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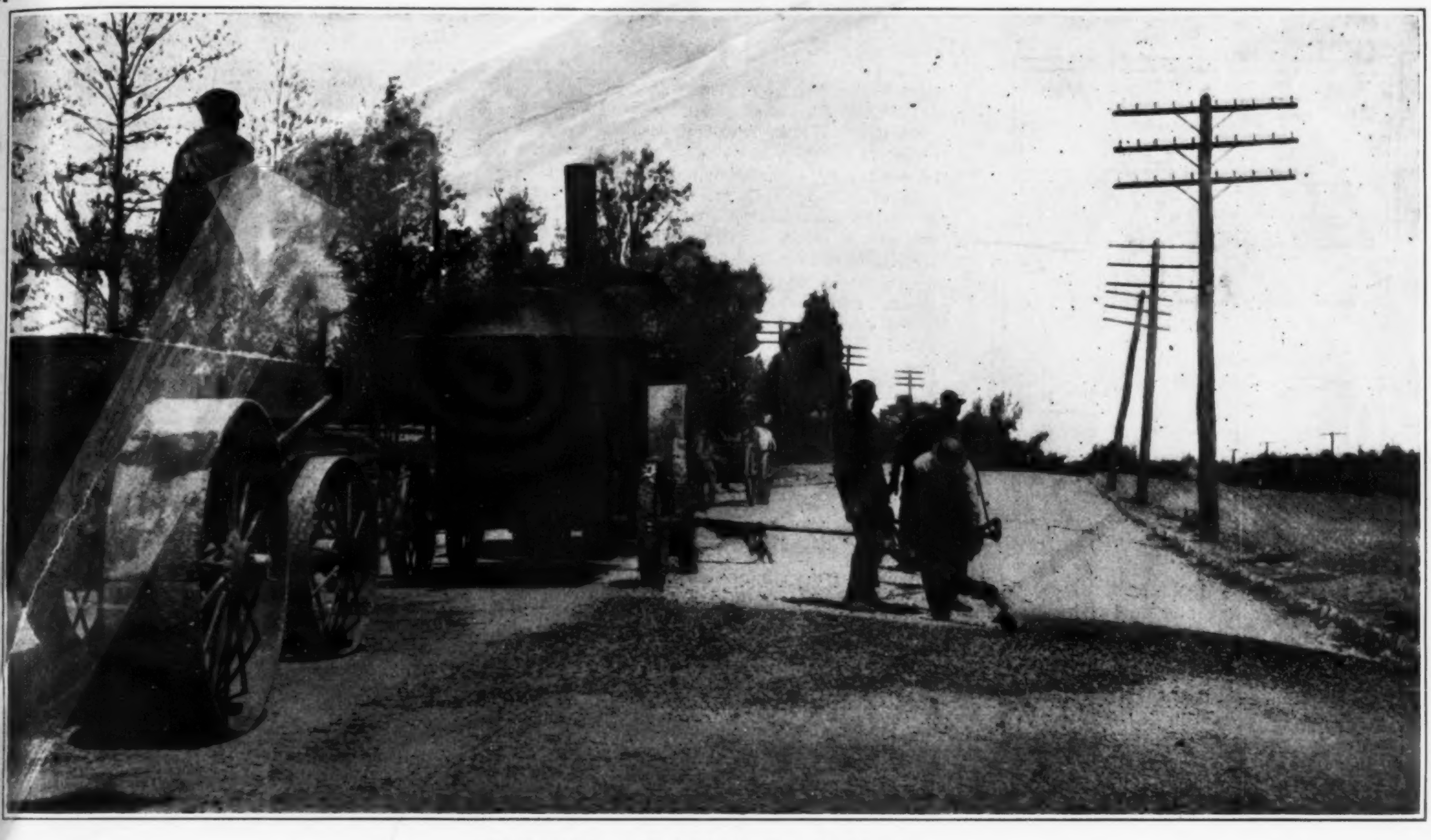

Constructing a road at Atlanta, Ga. Applying tar.

Laying a brick road at Ithaca, N. Y.

PERMANENT ROADS AN ECONOMIC NECESSITY.—[See page 168.]

The Ostwald Process for Making Nitric Acid from Ammonia

Its Proposed Combination With the Manufacture of Calcium Cyanamide

The Ostwald process for making nitric acid from ammonia, which attracted considerable attention some ten years ago, has recently entered into a new stage of its commercial development in connection with the formation of the Nitrogen Products and Carbide Company, Ltd. This new British company issued in May a

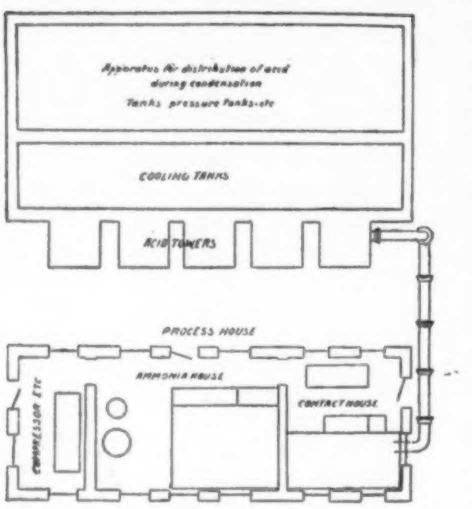

Fig. 1.—General plan of plant.

prospectus calling for a capital of $10,000,000. Among its directors are Mr. Albert Vickers, chairman of Vickers, Ltd., and Sir Richard Awdry of the Nobel Dynamite Trust Company, Ltd.

Among the products of this new company will be calcium carbide and calcium cyanamide, and the latter is to be employed to yield the ammonia needed as raw material for the manufacture of nitric acid by the Ostwald process. Use is here made of a well-known reaction by which ammonia is produced by heating cyanamide in the presence of water $CaCN_2 + 3H_2O = CaCO_3 + 2NH_3$. This reaction has been employed in some European works for the production of ammonium sulphate from cyanamide. The present proposal to work up the ammonia into nitric acid by the Ostwald process is novel.

The Ostwald process for making nitric acid from crude ammonia liquor is the subject of a long article in the *Iron and Coal Trades Review* (London) of May 23rd, 1913. This is reproduced in the following almost in full.

The fact that ammonia could be oxidized to nitric acid in the presence of atmospheric oxygen by the catalytic action of platinum was discovered by Kuhlmann about 1830. He was engaged in industrial work and, therefore, tried to apply this reaction in the commercial manufacture of nitric acid, but the time was an unfortunate one.

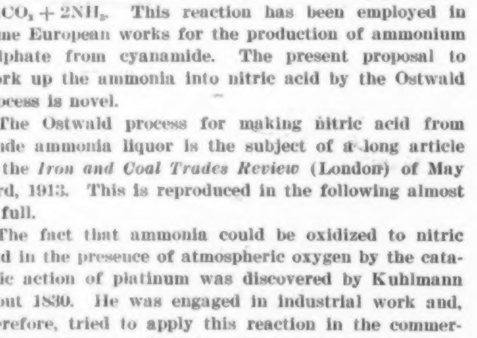

Fig. 2.—Plan of ammonia house.

The great beds of sodium nitrate, on which we still depend for our nitric acid, were just being developed, and the price of nitric acid was falling rapidly in consequence.

Besides this, there was no great production of ammonia or nitrogenous compounds, such as exists at the present time; by-product coke was not yet known, and there was no source of cheap ammonia.

The facts discovered by Kuhlmann, therefore, remained without commercial significance until within the last ten years, though the fundamental reaction, viz., the oxidation of ammonia to nitric acid in the presence of platinum, has been shown to every student of chemistry.

In 1900 Prof. Ostwald and his assistant, Dr. Brauer, began to work on this same old reaction, having in view the application to a commercial process. At the end of about three years of investigation in the laboratory on a comparatively small scale, the process was considered ready for a test on a small commercial scale, and a year or so later the first commercial plant—a small one—was erected. This was studied with a view to the elimination of all possible sources of trouble and much time and labor have been spent in finding proper materials for the various parts of the apparatus, and in working out a completely automatic process.

About six years ago a full sized plant was begun, the results on the commercial experiment plant being by this time so satisfactory as to warrant the step. This large plant converted about 25 tons of ammonia gas per month into about 150 tons of rather dilute (36 deg. Baume) commercial nitric acid.

The chemical reaction is a very simple one. Ammonia gas mixed with air is passed over a plug of platinum, so arranged as to expose a large surface of contact to the gases which are forced through it. The reaction is:

$$\underset{(17)}{NH_3} + \underset{(64)}{4O} = \underset{(63)}{NHO_3} + \underset{(18)}{H_2O}$$

For every seventeen parts by weight of ammonia used, 63 parts by weight of absolute nitric acid is formed.

Not long after the beginning of the experimental investigation of the reaction, an important fact was discovered. If the mixture of ammonia and air was allowed to pass slowly through the platinum contact, the yield of nitric acid was very small; only a few per cent of the theoretical yield were obtained.

If the stream of gas was forced quickly through the contact the yield was very nearly the theoretical value. This is to be explained by the fact that nitric acid is not the final product of the oxidation of ammonia, but only one of the intermediate ones. The final product is nitrogen gas and water.

So in the commercial plant the stream of ammonia mixed with air is sent through the platinum contact plugs at a high rate of speed, and the result is a very high percentage of the theoretical yield, and a high efficiency of the apparatus used.

Dr. Ostwald in his patent No. 698, of 1902, describes his invention as follows:

"It is well known that nitric acid can be obtained from ammonia through the oxygen of the air by means of the catalytic action of spongy platinum or platinum black, although up to the present no process is known for thoroughly effecting this change in a useful technical matter. I have ascertained that under the influence of compact platinum alone, or platinum that is partly covered with spongy platinum or platinum black, a mixture of ammonia with an excess of air can be oxidized to nitric acid or to a higher oxide of nitrogen.

"Besides the oxidation of the ammonia to form nitric acid or higher oxides of nitrogen, another reaction usually takes place which leads to the formation of free nitrogen. In order, therefore, to attain a technically useful process the operation must be so conducted that the first reaction is thorough and practically complete, while the second should be as small as possible.

"This result is attained by using, for example, smooth or solid platinum which is either employed direct in this state or is first either partly or entirely coated with a layer of spongy or of black platinum. When now a mixture of ammonia with ten or more times the volume of atmospheric air is directed over it, a fairly high velocity being maintained, and simultaneously the temperature brought to red-glow heat and kept at the same, the smooth platinum causes the ammonia to be burnt to nitric acid, the second reaction which produces free nitrogen being practically unnoticeable.

"The finely divided platinum on the other hand accelerates both reactions, the second one more than the first. By moderate use of the finely divided platinum (platinum black or platinum sponge) with the smooth platinum the operation can be so performed that the reaction takes place rapidly but without any great formation of free nitrogen.

"The form of catalyser to comply with these conditions may vary. If platinum is employed generally a length of one to two centimeters of platinum, over which the gas mixture streams with a velocity of one to five meters per second, is found to be sufficient; when the flow velocity is less, a shorter layer of platinum may be used."

In Patent No. 8,300 of 1902, Dr. Ostwald says: "The mixture of ammonia and oxygen (air) should contain a large amount of oxygen with reference to the quantity of ammonia, it being necessary that a quantity of oxygen should be present corresponding at least to that represented by the following equation:

$$2NH_3 + 7O = 2NO_2 + 3H_2O$$

"It is, however, advisable to use a larger quantity of oxygen, preferably in the form of air. A further condition for obtaining a practical result is that the temperature employed in the process should exceed 300 deg.

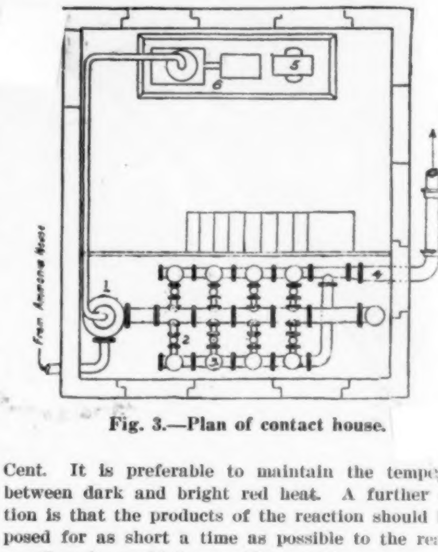

Fig. 3.—Plan of contact house.

Cent. It is preferable to maintain the temperature between dark and bright red heat. A further condition is that the products of the reaction should be exposed for as short a time as possible to the reaction, as otherwise rapid decomposition of the products would result. For this reason I employ catalysers as short as possible and cause the gases to pass over them at a high velocity. I have found it advisable to so arrange the length of the catalysers and the velocity of the gases in such a manner that the contact of the latter with the former should not exceed one hundredth of a second.

"As the velocity of the gases should be as high as possible, and also the temperature suitable for the oxidation should be maintained, it is necessary to maintain the velocity of the gases constant. This shows, however, practical difficulties. By a reduction of the velocity of the gases the catalysers would have a low temperature, as the heat of reaction developed in a unity of time would be smaller. By raising the velocity of the gases excessive heating of the catalysers would be caused. For the purpose of avoiding the aforesaid difficulties, I heat the gases to be treated by means of the hot products of the reaction before they come into contact with the catalysers."

The plant required to carry out this process on a commercial scale in connection with a source of ammonia consists of three parts: (1) Apparatus for pro-

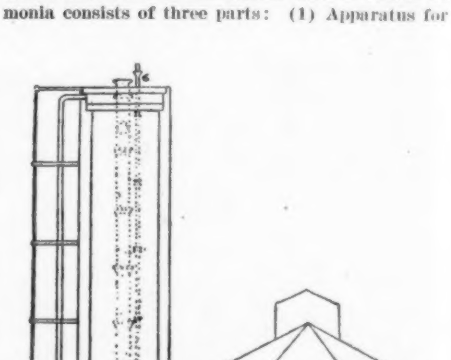

Fig. 4.—Condensing plant.

ducing ammonia gas. (2) Apparatus for the actual reaction, or catalysers. (3) Condensing plant.

Fig. 1 shows a general plan of such a plant and indicates the relative space occupied by the various parts. It is adapted to the use of ammonia liquor. In the case of using cyanamide small modifications in the ammonia plant would be necessary. The ammonia plant takes in crude gas liquor and sends out nearly pure, dry ammonia gas, freed from carbon dioxide and hydrogen sulphide. The gas is not freed from the traces of organic materials which may come over with it, for these impurities have been shown to exert no harmful influence on the process.

The ammonia plant for using gas liquor is a standard one, similar to those in use generally. This apparatus is indicated in Fig. 2. The crude gas liquor is received in the heating apparatus numbered 1 and 2, and to assist in driving out the ammonia gas, heat and current of air are both used. The gas so drawn off is purified in 3, 4, 5, and 6, by washing and treating with milk of lime. The current of air is supplied by a small compressor.

The air so supplied furnishes a portion of the oxygen necessary for the reaction, and its amount is regulated by automatic differential manometer and regulating valve. The rate at which the crude gas liquor and the steam are supplied is regulated by hand. The production of ammonia gas by the above apparatus must be perfectly continuous to be efficient.

Mixed with a small amount of air the ammonia gas then passes into the contact house or catalyser house. Here it is mixed with more air, supplied with a fan, and the mixture is regulated by the automatic differential manometer and regulator 1 of Fig. 3. The gas mixture then passes through the platinum contacts 3, by way of the cocks 2, so arranged that any contact can be cut out of service without disturbing the rest. Here the real reaction takes place. Up to this point only ammonia gas and air have been present, and either cast or wrought-iron piping can be used with perfect safety. In the reaction apparatus itself nitric acid vapors, at a high temperature are to be handled. As soon as liquid nitric acid begins to form, stoneware is the only available material.

The hot gases leave the reaction plant through the pipe 4 and pass to the condensing plant, which is shown in Fig. 4. The gases pass into the condensing towers at 1 and meet with a large cooling surface, which is wet by nitric acid trickling continually through the stone filling of the tower. Water is not used because as strong an acid as possible is desired and enough water passes along as the result of the reaction itself.

The condensation serves a double purpose. The nitric acid formed during the reaction, and the water formed, are condensed together to liquid nitric acid. Beside this, any other of the higher oxides of nitrogen which may have been produced are given time to oxidize further, to meet with water and to change to nitric acid. The nitric acid which has been allowed to flow down through the towers is, therefore, used over and over again, becoming stronger in the process. This acid is cooled in the cooling apparatus 3, before sending it back to the tower, and stored in the storage tanks 4 during the interim.

From 4 it flows into the pressure apparatus 5, and from here it is forced by air pressure back to the top of the tower. Three coolers and one storage tank are used in supplying cooled acid to each tower.

The plant shown in Fig. 1 has five towers, each about 60 feet high, and all acid is transported through stoneware. Whenever acid is to be lifted this is accomplished by air pressure.

From the opening of the last tower there escape nitrogen, oxygen, and a small amount of uncondensed acid, which can be further treated if desired.

It will be noticed that the condensing plant is an important part of the process. The gases from the reaction chamber pass through the five towers, one after the other, and this large condensing surface is necessary to prevent loss. The acid is tapped off at the foot of the second tower, and here it has a density of about 36 deg. Baume. It is a pure, not very strong, commercial grade of nitric acid.

Ammonia is the only raw material used in large quantity. A small amount of lime is also needed in the driving off and purifying of the ammonia gas. The product, nitric acid (36 deg. Baumé), is a current market chemical. The demand for this strength is, however, not very great, and a more concentrated acid, such as is used for making explosives, is more in request. The average price of ammonia in crude gas liquor, taken all over England, is not far from 10 cents per pound.

ESTIMATE OF PROFITS.

The following is an estimate of the profits of a plant for the production of nitric acid from ammonia from the Ostwald process. As a basis it is assumed that each catalyser produces 200 kilogrammes of nitric acid (36 deg. Baumé) in 24 hours, and a plant will be taken employing monthly 25 tons of nitrogen (N) equivalent to 830 kilogrammes of ammonia (NH_3) per day—to produce nitric acid.

These 25 tons of nitrogen, or about 115 tons of sulphate of ammonia, can easily be obtained from 64 by-product coke ovens. In a gas works we must consider for this purpose a production of about 120,000 cubic meters (4,237,990 cubic feet) in 24 hours.

Out of these 25 tons of nitrogen per month—which corresponds with 83 cubic meters of 1 per cent ammoniacal liquor in 24 hours—we should be able to get, by means of the Ostwald process (taking as a basis a yield of only 85 per cent), the following quantities of different concentrations of acid: Absolute nitric acid 78.7 tons per month; 93 per cent acid, or 48 deg. Baumé, 85.6 tons per month; 53 per cent acid, or 36 deg. Baumé, 148.4 tons per month. The last named product is produced directly by the process; the 93 per cent acid is obtained from the 53 per cent acid by concentration; the "absolute" acid is not steady at all.

For the manufacture of nitrate of ammonia this quantity of nitric acid—say 148.4 tons of 53 per cent—can be used by adding, say, 21 tons of ammonia per month; therefore, from a total quantity of 46 tons of ammonia per month we should get 99 tons of nitrate of ammonia (allowing 2 per cent as waste) as monthly yield.

The cost of a plant producing 148.4 tons of 53 per cent acid per month by means of the conversion of 25 tons of ammoniacal nitrogen into 53 per cent nitric acid is estimated as follows:

Plant for generating ammonia from gas liquor.	$7,500
Plant for conversion (catalysers)	5,000
Condensing plant	17,500
Foundations for towers and iron work	5,000
Acid storage tanks	750
Air compressor and motor	3,000
Platinum (initial expense)	2,500
Buildings and foundations	10,000
Unforeseen outlays	3,750
Total	$55,000

RUNNING EXPENSES.

(1) *Steam.*—The same quantity will be required as that to volatilize ammonia out of diluted liquor for other purposes—for instance, for the manufacture of sulphate of ammonia—that is, 20 to 25 kilogrammes of steam per 100 kilogrammes of 1 per cent ammonia liquor. As 83 cubic meters of ammonia liquor are used in 24 hours, 20,000 kilogrammes of steam may be allowed. Taking 100 kilogrammes of coal at the rate of 46 cents there would be a daily cost of $12.50, or monthly, say, $337.50.

(2) *Cooling water.*—A consumption of 200 cubic meters per day may be allowed; this, estimated at something more than a farthing per cubic meter, amounts to $1.50 per day, or $45 per month.

(3) *Power.*—To lift the liquid in the condensing house, and for direct air pressure, 12 to 15 horse-power are required and for the running of a fan a further 5 horse-power—that is, 20 horse-power altogether. This means per month 14,400 horse-power hours, and at the rate of 3 cents this amounts to about $437.50.

(4) *Lime.*—In employing a carbonic acid absorber, the consumption is something more than 1 kilogramme of lime (CaO) per kilogramme of ammonia (NH3). In consequence, something like 30 tons of lime are used per month. Figuring the ton at $3.75 this represents $112.50.

(5) *Platinum.*—For the whole plant 30 contact elements are required, having a weight of 50 grammes, which for a daily production of somewhat more than 100 kilogrammes of nitric acid corresponds with 200 kilogrammes of 53 per cent acid per contact element. The wear and tear is not very considerable; it may be estimated at 1.5 grammes per day or 45 grammes in the month. The contact elements may be used for a month or six weeks, after which time they ought to be scrapped as old metal and replaced. For this exchange it is only necessary to estimate the difference in price between the old and the new metal, which represents about 6 cents per gramme. Assuming a monthly exchange, the outlay for all the contact elements requires about $95. The total expense for platinum amounts to $140 per month.

(6) *Wages.*—For superintending and reversing of valves and cocks two men are sufficient per shift; for cleaning, a third man is required—altogether six men per 24 hours. Superintendence should not absorb more than $100 per month.

The cost of manufacture per month, including repairs and superintendence, is shown in foregoing table:

Steam	$337.50
Cooling water	45.00
Power	437.50
Lime	112.50
Platinum	140.00
Wages	202.50
Repairs	125.00
Superintendence	100.00
Interest and depreciation (15% on $55,000) per month	687.50
Total	$2,187.50

The cost of ammonia in the form of dilute gas liquor is calculated at the rate of $17.50 per 100 kilogrammes. The total quantity required amounts to $4,375 for the 25 tons needed for this size plant. The yield represents 148.4 tons of 53 per cent nitric acid. Reckoning the 100 kilos at $6, the receipts amount to $8,902.50.

From these figures it would seem that the operation of a plant for converting monthly 25 tons of ammoniacal nitrogen from the ordinary liquor of gas works, etc., into 53 per cent nitric acid gives the following results:

	Total per month	Per 100 kilos of 53% acid
25 tons of ammonia	$4,375.00	$2.95
Cost of conversion	2,187.50	1.46
Cost of production	$6,562.50	$4.41
Sales of 14,840 kilograms of nitric acid at $6	8,902.50	6.00
Net profit per month	$2,340.00	$1.59

The above figures of estimated cost, reproduced from the (London) *Iron and Coal Trades Review*, are of course, based on British conditions. For American conditions various of the figures would have to be changed. The figures are given here as they may serve as a basis of a modified calculation.

THE MANUFACTURE OF AMMONIUM NITRATE.

Ammonium nitrate is a valuable chemical and there is a large demand for it for safety explosives of all kinds. The market price is fixed by the value of ammonia and that of Chile saltpeter.

The Ostwald process is remarkably well adapted to the manufacture of ammonium nitrate. The nitrate acid is neutralized with a further supply of ammonia, and the solution of ammonium nitrate so obtained is evaporated until crystallization occurs. The neutralization is carried out in wooden tanks and the liquid is then evaporated in vacuum pans almost to dryness. Pure ammonium nitrate separates, and this is dried in centrifugals and packed for shipment. The impure salt left in the mother liquid is dried out and sold as second grade.

There must also be erected a plant to obtain pure ammonia out of the diluted liquor, and an installation for the production of the solid salt. For this purpose different combinations are possible, according to the mode of working, viz., to get the nitrate of ammonia direct from the gas or from diluted liquors and again either refining the salt produced before or after its formation.

In consequence the cost of an installation will vary between $25,000 and $35,000—buildings included. This for a production of 99 tons of nitrate of ammonia per month, and in which case we have to use altogether 46 tons of ammonia; out of which—as stated above—25 tons are for nitric acid, and the remaining 21 tons for pure ammonia.

Taking the price of nitrate for explosives at $17 per 100 kilogrammes, and reckoning for the purification of 21,000 kilogrammes of ammonia $1,050 and further for the preparing of 90 tons of salt, another $990 as wages, etc., the profits of this plant are established as follows, (the figures again referring to conditions in Great Britain):

	Total per month	Per 100 kilograms of salt
Value of ammonia, 46,000 kilograms at 17.5 cents	$8,050.00	$8.13
Of which 25,000 kilograms converted into acid—wages and depreciation	2,187.50	2.21
Purification of the remaining 21,000 kilograms of ammonia	1,050.00	1.07
Wages for manufacture of salt	990.00	1.00
Cost of production for 99 tons of nitrate of ammonia	$12,277.50	$12.41
Receipts from 99,000 kilos at 8½	16,830.00	17.00
Net profit per month	$4,552.50	$4.59

It may be estimated that the normal production of nitric acid in the United Kingdom is approximately 25,000 tons per annum, reckoning the acid as being 80 Tw. In ordinary years the amount used up on the spot will be about 20,000 tons, rising to 30,000 tons when the explosives trade is brisk. The miscellaneous trade will account for 5,000 to 7,500 tons according to requirements.

The Maintenance and Operation of Superheater Locomotives*

Conditions for Securing the Economies of Which the System is Capable

By Gilbert E. Ryder

The presence of moisture or condensation in the cylinders of all types of engines using saturated steam has been recognized since the early days of steam engineering as constituting the greatest loss attending their operation. While it has been known that this loss could have been greatly reduced, and completely avoided, as later experience has shown, by the use of superheated steam, it is only within the past few years that this use has come to be adopted generally. Attempts were made to employ superheated steam in the operation of steam engines as early as the year 1830, and careful experiments were made again some twenty years later. These experiments were all carried on with a view of using low or moderate degrees of superheat. The results showed that it was possible, by this means, only to slightly reduce the condensation. The lack of a proper lubricant to resist the temperatures of steam with higher degree of superheat, together with the introduction of the practice of compounding and the employment of relatively high steam pressures, resulted in the abandonment of experiments with superheated steam at that time.

About twenty years ago Dr. Schmidt began experiments with a superheater furnishing steam with a high degree of superheat. The results of these experiments proved so successful that about five years later the superheater became practically established as part of the equipment for locomotives on the Prussian State Railways, where the trials were made. From that time to the present over twelve thousand superheaters have been applied to locomotives on European railroads, and it is an interesting fact, in connection with this rapid advance in the adoption of superheaters on European roads, to note that the general principles of the design remain very nearly the same as in the first superheaters built.

While superheating became popular in Europe fifteen years ago, it was not adopted generally in this country until about three years ago. Its success, however, became established in America at the time when the need was most felt for some means of increasing the efficiency of the locomotive. It was at a time when there was considerable legislation adverse to railroads on the one hand and rapidly increasing cost of operation on the other, resulting in the reduction of the net earnings of the railroads and making economy emphatically necessary. That the superheater met the emergency is a matter of record and that the records were satisfactory is established by the extent of its adoption. In this period of about three years there have been approximately seven thousand superheaters applied to locomotives on American railroads.

CONSTRUCTION AND ECONOMY.

The construction of the Schmidt superheater, which has come to be recognized as the standard used by practically all railroads in this country, is no doubt familiar to most railroad men. The principle followed in the design of this superheater is that of the disposition of coils or units in the large boiler flues. The forward ends of these units are connected with a receiver or collector casting, known as the header, which takes the place of the ordinary tee head in saturated steam practice and like the tee head is located in the upper part of the smoke-box. The superheater units consist of four 1½-inch outside diameter cold drawn seamless steel tubes, connected together by cast steel return bends, extending to within two feet of the firebox tube sheets. In their location in the large flues they are exposed to the temperature of the gases from the firebox, which range from sixteen hundred to six hundred degrees throughout the length of the tube. The steam passing through these pipes, and subjected to this range of temperature is superheated to 200 or 250 degrees. The effect of raising the temperature of the steam to these high temperatures is that of making it capable of passing through the cylinders without condensation. Superheat does not increase the pressure nor raise the mean effective pressure of the steam. While it does temporarily increase the specific volume of the steam about 30 per cent above that of saturated steam at the same pressure, some of this increase in specific volume is lost between the superheater and the point of cutoff. While it may leave the superheater with from 200 to 250 degrees of superheat, it will have left probably about 100 degrees at the point of cutoff. The saving that is obtained results from the entire elimination of all losses through cylinder condensation, together with that obtained by the remaining increased volume of the steam. These savings, under average conditions, amount to approximately 30 per cent in steam or water consumption, which corresponds to the saving in fuel of from 20 to 25 per cent compared with saturated locomotives working under the same conditions. It thereby provides an increased hauling capacity, which, using the coal saving as a basis, amounts to from 30 to 35 per cent.

OPERATION AND MAINTENANCE EXPERIENCE.

While these savings represent what is possible to obtain with the superheater, they depend largely upon proper methods of operation and maintenance. This then brings us to the subjects in which the Mechanical Departments of railroads are most interested, that is, maintenance and operation, for, while we are all more or less interested in the design and construction of the apparatus, this interest on the part of the mechanical railroad men is viewed from the standpoint of simplicity in design to the end that it may be accessible for maintenance and economical in operation. While the methods employed do not differ materially from the proper methods to be followed in the maintenance of saturated steam locomotives, there are some points which require special attention. The importance of giving attention to these special features can only be realized by experience and it is often the case when the first superheaters go into service on railroads that difficulties are encountered, which disappear after the superheaters have been in service for some time and the men who care for them at the terminals, as well as the engineers and firemen, become more familiar with their peculiarities.

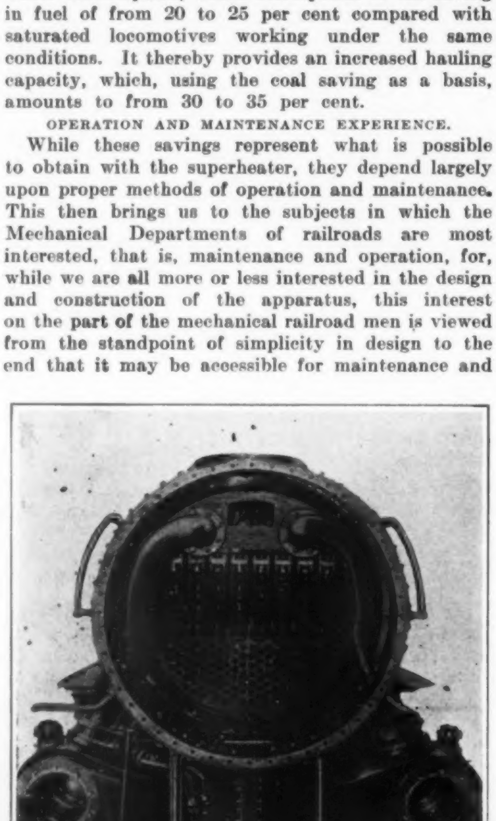

Fig. 1.—A top header fire tube superheater applied to locomotives with outside steam pipes.

LEAKS.—FRONT FLUE SHEET BALL JOINTS.

In the maintenance of superheater locomotives proper care at the time the locomotives are received has much to do with their successful operation and the amount of attention that must be given them during the rest of the time that they are in service. The principal troubles that are experienced at the outset are leaks in the front flue sheet and leaks in the ball joint connections bewteen the units and the headers. In order to prevent serious trouble resulting from these leaks later on, it is found to be a good practice to test the boiler for leaks in the front flue sheet after the engine has made two or three trips, and at the same time the superheater may be tested for leaks in the ball joint connections. It requires very little time to make these tests and the leaks may be repaired while they are small, before any serious damage is done. Leaks that are discovered in the ball joint connections at this time may, in a great many instances, be stopped by merely tightening the nuts on the unit bolts. It is also a good practice, at this time, to go over all the unit bolts and take up whatever is possible on them, whether any leaks show in the ball joint connections or not. The heating and cooling of the bolts when they are first applied seems often to have a tendency to stretch them and it is often possible to take up a part or even a full turn on the nuts.

The seriousness of leaks in the front flue sheet or in the unit joints can best be illustrated by instances where they have occurred and have been allowed to run without proper attention. One instance recently came to my notice where the front flue sheet had cracked; the steam from the crack impinging on one of the unit pipes had cut a hole ¾ inch in diameter in it. The steam from the hole in the unit pipe and from the crack in the front flue sheet, together with the cinder, completely stopped up several of the large flues with a mass of cinder and scale baked so hard that it was almost impossible to remove the unit. A leak of this kind must have been going on for a considerable length of time in order to have cut so large a hole in the unit pipe and had inspection and tests been made the trouble would have been located and repairs made before it had gone so far, and it would not have been necessary to make such extensive repairs. This instance also illustrates to what extent these conditions may exist and locomotives still not fail entirely for steam.

FLUE SETTING.

The methods of setting superheater flues are practically the same as those followed in the setting of small boiler flues, except that the large flues are beaded in the front flue sheet, as well as in the firebox sheet. In preparing the sheet to receive the large flues the hole should be chamferred in the sheets to remove any burr that may be left by the cutting tool and also to remove the sharp edge, thereby reducing the liability of its cutting into the ferrule of the flue. The use of copper ferrules is, of course, recommended without exception and the ferrule used in connection with superheater flues is somewhat heavier than that used in the ordinary flue.

FLUE MAINTENANCE.

In the maintenance of flues too much emphasis cannot be placed upon the standardization of prossers, rollers and beading tools. Prossers of various contours used in the same flue operate more to its damage than to its good. The contour of the prosser used in the first working of the flues after they have been set, should be maintained throughout the life of the flue. Experience has proved that the prosser with less than twelve sections should not be used. The roller which has given the best service is one with at least five rolls. The three-roll roller similar to the one used in rolling the small boiler tubes, has been found to be too severe on the large flues, on account of the liability of setting the rolls too far into the flue and of rolling up the metal between the rollers. As it becomes necessary to work the flues from time to time, the best results will be obtained if the prosser is given preference and the rollers and beading tools used only when the conditions are such that their use cannot be avoided.

SAFE ENDING.

The large flues are safe ended when safe ending is necessary on the back end or firebox end of the flue. The method of swaging the flues to a standard diameter of 4½ inches is done to facilitate the safe ending. The practice of safe ending the back end of the flue makes it necessary to carry but one size of safe ending material in stock and brings the operation of safe ending within the range of many of the flue welding machines now installed in many railroad shops. The swaged portion of the flue is about 6 inches long and the distance from this part of the flue to the end of the superheater unit is about 18 inches and safe ends should be as short as possible in order to increase the number of safe ends applied before it becomes necessary to reswage the flue, which will occur when the small part of the flue interferes with the end of the unit. In applying safe ends after the first time, it is advisable to cut off the flue far enough back to remove the old weld, thereby providing that there be only one weld in the flue. The principal reasons for safe ending the back or small end of the flue are, briefly, because it provides material at the firebox end of the flue where the service is most severe. The small or swaged end of the flue being less in diameter

* Paper read before the Railway Club of Pittsburgh.

the cost of safe ending material is less, and inasmuch as the diameter of the small portion is standard for both the 5½ inch and 5⅜ inch flues, it is necessary to carry but one size of safe end material in stock.

FLUE CLEANING.

The flue cleaning question is *always* a vital one whether it be in the saturated steam locomotive or the superheater locomotive, and the superheater often is blamed when a condition of the superheater flues exists which would not be tolerated with the ordinary tubes. The thorough cleaning of boiler tubes is, beyond doubt, of very great importance, for on it depends the primary function of the boiler, namely, the transference of heat from the gases to the water. The medium at best is poor, but when it is allowed to become coated and incrusted with a poor conductor of heat the loss is great.

It is often forgotten, by those who find the flue cleaning a considerable problem, that it was necessary sometimes to clean flues before the advent of the superheater; and that it was often necessary to take flues out of saturated engines because they were stopped so badly that it was impossible to bore them out. In other words, the flue cleaning problem did not begin with the introduction of the superheater, and stopped-up flues should not be charged entirely to it. It is very nearly always the case, when our traveling engineers report that superheater flues are stopped up, they have found a large percentage of the small tubes in the boiler stopped up as well.

As to the method of cleaning flues, it consists simply of inserting a ⅜-inch pipe connected to the roundhouse air line into the back end of the flue and blowing the soot out the front end. the pipe being long enough to extend entirely through the flue; the air pressure should be about 100 pounds.

DAMPERS.

There has been considerable controversy recently as to whether the operation of superheater locomotives without dampers would be detrimental. The omission of the damper may not, and probably will not, result in any immediate trouble. Eventually, however, there will be trouble from leaky unit pipes resulting from the action of high temperatures that they are exposed to when there is no steam within them to absorb the heat. In other words, the operation of the locomotive without the damper will shorten the life of the superheater units and the trouble may come immediately or it may be after the engine has been in service one or two years. The fact that the omission of the damper will not cause any immediate trouble, makes it impossible to put much faith in the reports that good results are being obtained without dampers until they have been run in this manner throughout the life of the superheater. It will take some time for the trouble to develop and no doubt roads operating extensively without dampers will sooner or later experience trouble from leaks in the unit pipes at points nearest the firebox, where they are subject to the highest temperature.

COST.

From the foregoing it might be inferred that there is considerable increase in the maintenance cost of the superheater over the saturated locomotive. This is not, however, the case. While there are no figures available as to the actual maintenance cost per ton mile, circumstances make it conservative to say that it costs at least no more to maintain a superheater locomotive than it does a like saturated locomotive. One large railroad that has about 800 superheaters in service finds that it has not been necessary to increase their roundhouse organization at any point on account of additional work necessary to maintain the superheater.

OPERATION.

The main difference in the operation of superheater locomotives compared with that of saturated locomotives lies entirely in the reserve power that the superheater locomotive is capable of developing. It is very difficult for an engineer, who has been operating a saturated locomotive, where it is a continual fight for steam, to realize that with a superheater locomotive it is possible to work the engine lower down or with a longer cut-off without the steam pressure falling back.

It is a fact that the efficiency of the superheater increases as the demand for power increases. This point can be illustrated best by examples that come to our attention every day, showing the possibilities that lie in following proper operation methods.

The fear on the part of engineers to take advantage of the reserve power that is available is illustrated by the following incident: The engineer had been operating a saturated locomotive and having considerable difficulty in getting over the road and maintaining the schedule with seven or eight cars. A superheater locomotive was given him and he was running her practically the same way that he had operated the saturated locomotive. There was one particularly difficult portion of the road where a slow order to ten miles per hour was in force across a long bridge. Directly upon leaving the bridge it was necessary to negotiate a 1 per cent grade. The representative of the Superheater Company was on the locomotive and suggested to the engineer that he work the engine at least half stroke up the grade. After some little persuasion he was prevailed upon to take a chance in spite of his fear that the water would get away from him. It is needless to say that the locomotive pulled nine cars up the 1 per cent grade, accelerated from 10 to 45 miles an hour before the lever was hooked up and without any variation in the steam pressure or any damage by low water except that of wearing out the gage cocks while watching the water. Another instance that I know of was the Mikado locomotive on a 3/10 per cent grade with an adjusted tonnage of 5,000 tons, which is equaivlent to about 4,700 tons actual. When on the grade it was decided to see how far the lever could be dropped before the engine would fail for steam. It was dropped one notch at a time until it was clear in the corner. One injector was on full and the other injector worked intermittently. The speed was accelerated to 18 or 20 miles an hour and the pressure did not drop below 190 pounds. These two instances illustrate the power that is available with a superheater locomotive, but it must be operated right to get all out of the engine that there is in her.

FIRING.

In the operation of the superheater locomotive it may be said in general that what is good for the saturated locomotive is also good for the superheater locomotive. The fire carried should be level and as even as conditions will permit, firing light

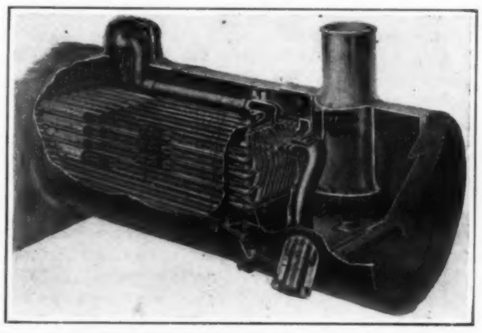

Fig. 2.—Top header fire tube superheater.

and regular and maintaining a bright white fire over the entire box. By following the proper methods of firing, higher temperatures can be maintained in the firebox, which means higher temperatures in the large flues and more superheat. On this subject I wish to quote from a discussion of a paper recently read before a railroad club:

"When we were making tests for temperatures, I had some particular observations taken of the firing conditions and found very remarkable results. We found that the temperature with the superheated steam was more constant and higher when a light fire was maintained and careful methods of firing were followed as against careless methods. For instance, leaving the door open or firing with a large number of scoops at a time, thus deadening the fire and then permitting it to die down before firing again. We had curves of temperatures that were very irregular."

FULL THROTTLE.

Another point that may be considered in the operation of superheater locomotives is that of running with a full open throttle wherever it is possible. There is always some drop in pressure between the throttle and the cylinders in any locomotive. This drop in the superheater locomotive is very little greater and will be increased still more by any wire drawing through the throttle. The best practice in operating the superheated locomotive is with a full throttle wherever the conditions permit, cutting back the reverse lever or reducing the cut-off if a reduction in power is required. This practice should be carried on until the point of most economical cut-off is reached, after which further reductions in power should be made by reducing the throttle opening.

HIGH WATER.

Another point that should be given particular attention in the operation of the superheater locomotive is that of carrying the water too high in the boiler, for the efficiency of the superheater may be greatly influenced by the water level. It has been said that the high water man, operating a saturated locomotive, needed a superheater to overcome the bad effects of this practice, and it is a fact that the superheater will help out the high-water man. It will be possible for him to carry water at almost any level without being able to detect its presence in the cylinders.

Records will show, however, that the high-water man is not getting the economy out of the superheater that is available, for the superheater is being used virtually as an auxiliary boiler to evaporate the moisture or water carried over. In other words, the heat that should go toward raising the temperature of the steam is being utilized to evaporate the water and the final temperature of the steam is much below what should be obtained and the efficiency of the superheater greatly impaired. It is not necessary in the operation of the superheater locomotive to carry the water so high as certain conditions in saturated practice demand. The superheater locomotive develops the same power on from 30 to 35 per cent less water, thereby reducing the liability of the water getting away with the same rapidity as it does in the operation of saturated locomotives when it is necessary to trade water for steam.

OIL FOR LUBRICATION.

With reference to the quality of oil used in superheater locomotives, it is only logical that an oil with a flash point higher than that ordinarily used in saturated engines is advisable. The oil that has been used for a good many years in saturated locomotives has a flash point of about 500 degrees and carbonizes at temperatures considerably below 500 degrees. Inasmuch as the temperature of the steam chest and cylinders is at times considerably higher than the flash point of this oil, it is necessary to provide oil with a higher flash point than that used in saturated practice. In spite of the fact that it has been demonstrated that oil with a flash point of 500 degrees may be raised to temperatures several hundred degrees above this point, while enveloped in steam, without impairing its lubricating qualities, it is not always possible to control this condition and keep the oil surrounded by steam while the parts to be lubricated are at a temperature above its flash point. There are times when the engine is shut off that the temperature of the steam chest and cylinder walls are above the flash point of the oil. Under these conditions the oil must necessarily carbonize and it is in order to meet these conditions and prevent the carbonization that an oil with a flash point approaching the maximum temperature of the cylinder and steam chest walls is recommended. After good material and good workmanship have been provided in the valves, cylinders, bushings and rings, and a good grade of oil has been secured, the proper distribution of this oil remains. This can be best effected by a five-feed lubricator, distributing oil to the steam chest and cylinders of the engine. The engineer can also facilitate the lubrication by slightly cracking the throttle while drifting, thereby keeping steam in the cylinders to protect the oil until the temperature has been reduced below the point where the oil is affected.

PISTON ROD PACKING.

There has been some trouble occasioned by the melting out of piston rod packing. Experiments have been made to meet this condition in which various packing mixtures have been used. The mixture which has given the best results is made up of 80 per cent lead and 20 per cent antimony, which has a melting point well above the temperature of the superheated steam. This mixture, however, is not infallible and there are instances where it has melted out in service. These instances do not point to the fact that the mixture is unsuited to the purpose, because piston rod packing is considered satisfactory in saturated steam practice and occasionally gives trouble by melting out. In the case of the superheater locomotive, as well as the saturated locomotive, the melting out of piston rod packing is not so much due to the high temperature of the steam. It is generally caused by too high temperatures generated by the friction between the packing and the rod, due to improper lubrication. This trouble may be avoided by correcting the lubrication and equipping the rods with a swab cup and using valve oil on the swab.

Upon the proper maintenance and proper operation depends the possibility of obtaining the savings and the advantages that are offered by the use of superheated steam. While it may appear from the points that have been mentioned that the cost of maintenance of the superheater locomotive is considerable, it is found in actual practice that the maintenance costs are not higher for the superheater equipment than for any other similar part of the locomotive.

Some Aspects of the Subject of Transportation*

III—Ocean Transportation

By Lieut-Col. J. E. Kuhn

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OCEAN TRANSPORTATION.

On the ocean water transportation attains its greatest economical development. Large carriers, long hauls, and mechanical power for driving the ship and for loading and unloading cargo have brought ocean freight for bulk commodities to as low a figure as ½ mill per ton mile. With the growth of the world's traffic, ocean tonnage has increased enormously, steam has replaced sails, and the size of carriers has increased tremendously. For 1911, the value of international trade is given at 30,000 millions of dollars, nearly all of which was carried in ocean bottoms. The share of the United States in this international trade amounted to 4,000 millions of dollars, or more than one eighth. In all countries there is a record-breaking activity in shipping and in ship construction, taxing shipyard and harbor facilities to the utmost. The growth of ocean traffic is but a reflection of the world's activities, and, as in the case of railroad transportation, the national response to increased consumption and production.

The item of chief interest in connection with ocean traffic is the size of the ship and whether there will be any limit in this direction. Upon this item depends the planning and carrying out of the costly works of harbor improvements now going on in all quarters, including both channels and docks. Not only have ships' dimensions been increasing, but during the last few years this increase has been at an accelerated rate. Up to 1900 the largest steamship, typified in the "Oceanic" of the White Star Line, had a length of 685 feet, a gross tonnage of 19,000 and a load draft of 30 feet. Since then the increase has been by leaps and bounds, culminating in the "Imperator" of the Hamburg-American Line, which recently made her maiden voyage, 880 feet long, 50,000 gross tons, and 34 feet load draft. A still larger vessel, the "Vaterland," 950 feet long and 100 feet beam, has just left the stocks. So far as mere construction is concerned, there is no reason why the already large dimension of ocean leviathans may not be considerably increased. The structural materials now available, and the introduction of the turbine engine, without counting on further improvements, have not yet placed a bar on further increases of dimensions. So far as the shipowner is concerned, his interests lie in the direction of larger ships, not only because of the fundamental economy in propulsion and the ability to attain increased speeds, but because of certain other advantages, among which may be mentioned:

1. Ability to maintain high speed in rough weather.
2. Greater steadiness and comfort to passengers.
3. Better and more spacious passenger accommodations.
4. The business attraction incident to having the largest, fastest and finest boats.

Up to a certain point an increase of size is unquestionably advantageous in the interests of steadiness and sustained sea speed. What this point is depends upon the size of storm waves and, judging by performance, is attained on the Atlantic by vessels in the express service of the great steamship companies, such as the vessels "Mauretania" and "Kaiser Wilhelm II," 700 to 800 feet long, and 30 feet load draft. Vessels of this type develop a speed of from 23 to 25 knots in all weathers, and maintain a regularity of service comparing favorably with the transcontinental express trains. Larger dimensions than those just quoted cannot be justified on the grounds of steadiness and sustained speed, and the latest dimensions attained in the "Olympic," "Imperator" and "Vaterland," owe their adoption to other causes, probably to the desire for increased passenger accommodations and for notoriety.

If, then, there is to be any limit to the growth in size of ships, it must be sought for in causes outside limitations of construction and ambitions of ship owners. Such a cause is found in the limitations of draft imposed by existing physical conditions in most of the seaports and harbors of the world. That this cause has already exercised an influence in the dimensions of ships is evident from the manner in which ships have grown, the increasing being mainly in length, breadth and molded depth, with relatively small increase in draft. Since 1900 the largest vessels show an increase of 35 per cent in length and breadth, as compared with only 10 to 12 per cent in load draft. The reason for this is obvious. The provision and maintenance of very deep approach channels, often of great length, and of deep water docks, impose expenditures and difficulties so large that even well intentioned government and port authorities may be excused for taking a reluctant attitude. That the demands of ship owners have been met in a generous spirit is evidenced by the costly works of harbor improvement now under way in all parts of the world. Staggering sums are being expended at the present time to provide accommodations for the large ships now in use, and one needs only to consider the vast engineering works at Bremen, Hamburg, Liverpool, London, Havre, New York, Buenos Aires, and other world ports to realize the obligations that have been imposed by the increased dimensions of vessels and the growth of the world's traffic.

It is not only in the matter of deeper and more commodious channels required, but also in the enlarged port facilities that the very large ships of to-day are giving concern. The piers, dry docks, wet docks, and quay walls to accommodate these ocean monsters are exceedingly costly, and must eventually operate to limit growth in size if consideration be given to economical returns. Hitherto the extraordinary growth of the world's commerce has enabled costly port works to be carried out under conditions which have either actually shown economic returns or have been considered justified by governments on the ground of general benefits, regardless of returns on capital expenditures. If, however, ships continue to increase at the present rate, it is certain that a point will be reached beyond which port and governmental authorities cannot go in the matter of providing accommodations. It may well be questioned whether we have not already reached a point where capital charges for channel and port improvements do not exceed the economies resulting from carriage in large ships.

As a matter of fact, the costly harbor accommodations now being provided serve relatively few ships, engaged in special service and plying between great centers of commerce and population. The great bulk of the world's carrying trade is still carried in ships of relatively modest dimensions, and not requiring excessive channel depths. An examination of the British register of merchant vessels for 1910 shows out of a total of 11,500 steel ships above 100 tons gross register, only 328 exceeding 7,000 tons, and only 20 exceeding 15,000 tons It is these very few large vessels, carrying an insignificant part of the world's commerce, which have forced the huge expenditures which are now being undertaken for port improvements It looks very much like a case of the tail wagging the dog.

The fact that we have the very large and fast steamers on our hands must be taken as prima facie evidence that their owners expect economical returns, either directly or indirectly. It must not, however, be overlooked that the express steamers of the great European steamship companies are in receipt of considerable subsidies from their governments. The "Mauretania" and "Lusitania" not only receive an annual subsidy of $750,000, but were built by a government loan of $13,000,000, at the low rate of 2¾ per cent, payable in twenty years. It is also noteworthy that a speed limit appears to have been reached in the case of these vessels, and that the latest additions to the roster of ocean giants are designed for slower speed and a larger cargo capacity, the latter feature being largely sacrificed in the fastest express boats. Where national prestige and national expenditures are concerned, as in the case of the building of large ships and the providing of berthing accommodations for them, economic considerations are often thrown to the winds. Demands of ship owners and rivalry of ports still further cloud the economic aspects of ocean traffic. But, in spite of all the factors operating to increase the size of ships, we may conclude that there is a limit to their growth, and that this limit, moreover, is not far from having been reached, owing to limitation in channel drafts and to harbor facilities.

The cost of dredging increases rapidly with increase of depth, not only because of the greater lift and reduced output of excavating machines, but also because at the greater depths harder material is encountered. What the addition of one foot in depth means in the case of a channel like that of the Delaware River is shown by the fact that for each additional foot of depth 10,000,000 cubic yards of original excavation must be made, costing at present average prices $1,500,000. At the depth now being sought, viz., 35 feet, the familiar Delaware River mud is changing to gravel, hardpan, cobblestones, boulders and some ledge rock, and unit prices are increasing. Much of the dredging-machinery now in use was not designed for work at such great depths as now required, and cannot be employed in all places. Some of the dredges now at work in the Delaware cannot dig at high tide, their booms and ladders not being long enough to reach bottom. Not only does the cost of dredging increase rapidly with depth, but also the cost of wet and dry docks, piers and quay walls. For the present 40 feet appears to be the limit of channel depth contemplated, a depth which has now been provided for New York harbor, the Panama Canal, and several European ports. This depth provides for the largest vessels now afloat or building, and leaves some margin for future increase.

In this country it is the policy of the National Government to provide the necessary approach channels to ocean ports and to fix the harbor lines beyond which encroachments by riparian owners is forbidden in the interests of navigation. Until very recently the development of port facilities has been left to the several riparian owners without any central or general control. In Europe and elsewhere a different policy generally prevails, the administration of the port as a whole, including the provision and maintenance of approach channels, being in the hands of a single body, a Board or Commission invested with the needful legal authority and deriving its funds from the sale of bonds, aided by contributions from the States and municipalities Charges are made for the facilities offered, and the revenues so derived are applied to the maintenance and improvement of the port and to pay capital charges.

The principal requirements of a successful ocean port are:

1. An approach channel of ample dimensions.
2. Ample dockage facilities.
3. Warehouse space.
4. Freight handling machinery.
5. Facilities for coaling and repairs.
6. Railroad connections.
7. A hinterland affording traffic possibilities.
8. Low port charges.
9. A unit control for the management and development of the port facilities.

Port administration as heretofore practiced in the United States has been characterized by haphazard methods and a general lack of any definite policy looking to future growth and development. Out of some 50 principal coast and lake harbors, only two, San Francisco and New Orleans, are at present adequately administered by a single authority operating under State laws. While other ports, like Boston, Philadelphia and Baltimore, have duly legalized port authorities, their usefulness is greatly curtailed by the fact that the greater part of the water front property is owned and controlled by private and corporate interests, mainly the railroads. Where such conditions prevail it is too much to hope that these interests will voluntarily improve their property in accordance with any general policy looking to the benefit of the port as a whole, even when such a course will ultimately redound to their own advantage. Nothing short of the exercise of eminent domain and the acquisition of water front property by municipalities or States will ever result in a systematic port development. Such port facilities as we now find at most of the harbors in the United States are due mainly to the railroads, which have constructed piers, tracks, elevators, coal and ore chutes, and other special structures to meet the requirements of their individual business, and

* Reproduced from the *Proceedings* of the Engineers' Club of Philadelphia.

which are generally free to vessels taking on or discharging cargo handled by the road. The generous attitude of the railroads toward vessels is made possible, of course, only by the absorption of the overhead charges for the terminal in the railway freight rate.

In the matter of approach channels, a minimum depth of 35 feet at mean low water may be regarded as essential to the requirements of an ocean port. This does not mean that a vessel can load to this draft, for she must needs have some clearance under her keel to allow for "squat" when under way, and to provide a margin for extraordinary low tides, which may fall two feet below the mean under certain directions of the wind. About 32 feet load draft is the maximum which should be attempted in a 35-foot channel at mean low water, and this is sufficient for the largest cargo steamers now in service. Of the competing ports on the North Atlantic seaboard, Montreal has a 30-foot channel, Boston 35 feet, New York 40 feet, Philadelphia 30 feet, with a 35-foot channel under way, and Baltimore 35 feet.

Boston's 35-foot channel is 7½ miles long and cost about $9,000,000; New York's 40-foot channel is 7 miles long, and cost about $5,500,000; Philadelphia's 35-foot channel is nearly 60 miles long, and will cost about $11,000,000; Baltimore's 35-foot channel is 24½ miles long, and cost $3,500,000. Large as these expenditures for deep approach channels may appear, they are justified by the heavy and constantly increasing tonnages. New York's port tonnage for last year, including both foreign and coastwise, amounted to about 200,000,000 tons; that of Philadelphia to 25,786,000 tons; and of Baltimore, 10,123,355 tons. Boston's foreign tonnage alone was 12,258,000 tons in 1911, with probably three times as much more in coastwise tonnage. In view of the heavy ocean traffic, large expenditures for ample channels at our ocean ports need no defense, and are much wiser than those made in the fruitless attempt to develop internal traffic on our river systems.

In the United States vessels are almost invariably docked at piers extending more or less at right angles to the approach channels. The more commodious water areas available in the United States ordinarily admits of this course, where in Europe, vessels are locked into basins at one side of the channels and made fast to quay walls. Piers must be at least as long as the vessels they are to accommodate, and with the constantly increasing dimensions of ships, the encroachment of the longer piers in channel widths is becoming a serious matter. This question is giving New York harbor serious concern at this moment, the Secretary of War having declined to permit of further pier extensions in the Chelsea district, where all the large express steamers dock. Piers must also have ample width to provide for the accommodation of cargo and passengers, the latest constructions showing widths of 300 feet. Slips separating piers should be not less than 150 feet wide, so that two vessels may lie in the same slip and still have space between them for lighters to come alongside.

In foreign ports much attention is devoted to freight handling machinery, to enable cargoes to be handled with dispatch. Traveling cranes, shear legs and like appliances are installed to handle package freight. In the United States little has been done in this direction save for handling bulk freight, like grain, ore and coal. At Boston, the Boston and Albany Railroad has a grain elevator designed to deliver 10,000 bushels of grain per hour to each of four hatches simultaneously, by a system of belt conveyors operated electrically. The elevated coal and ore pockets commonly in use enable a vessel to take on 7,000 or 8,000 tons in four or five hours. Since unnecessary delays in port are prejudicial to the interests of the port, it is important that docks be provided with the best and most rapid loading and unloading appliances, to enable vessels to make quick returns.

As most ocean freight is transit freight, it is of course important that terminals should have rail connections. The best results are obtained by tracks running directly on the pier and close alongside the ships' hulls, so that freight can be transferred directly between ship and car. Where several railroads and several docks serve the same port, a belt or connecting railway is essential.

Low port charges are necessary to attract trade, and any discriminations in this respect will injure the business of a port. As already mentioned, vessels using railroad owned terminals ordinarily pay no wharf charges when their cargoes are handled, in whole or in part, by the railroads, the use of the piers being free to the vessel, and being treated as an incident in the business of the railroad. In Philadelphia, independent pier owners make a charge of 1½ cents per ton per day for steamers and from ¾ to 1 cent per ton per day for other craft, based on net registered tonnage. The railroads do not even charge for freight delivered over the vessel's side into barges or lighters and destined for other points in the harbor, nor is any charge made for freight consigned locally and hauled away in trucks or drays. Freight not removed in 4 days is subject to a storage charge of 5 cents per 100 pounds for each 30 days or fraction thereof. Somewhat similar conditions obtain with railroad owned terminals at Baltimore and Boston. Other charges to which vessels using the port of Philadelphia are subject are the tonnage tax, pilotage, and tugboat service. The tonnage tax is a Federal tax, amounting to 2 cents per registered ton on vessels from Canada and the West Indies, and 6 cents per registered ton for vessels from other foreign ports, collected on five trips or less per year. From $150,000 to $200,000 is collected annually in tonnage taxes at the Port of Philadelphia.

Pilotage is charged at rates authorized by State laws, and amounts, roughly, to $5 per foot of draft. Tugboat charges are in accordance with schedule adopted by the Towboat Owners' Association, and vary with the carrying capacity of the vessel. For a vessel of 5,000 tons capacity, the towage charge between Philadelphia and the Capes in $155 inbound, and $312 outbound. For docking steamers two tugs at $15 each are charged.

The foregoing scales of charges to which vessels are subject prevail with small differences at Boston and Baltimore also. In New York many of the piers are municipally owned and rented to steamship companies. The Cunard and White Star Lines pay something like $70,000 annually per pier rented. The question of adequate port facilities is one of peculiar interest to Philadelphia, for the reason that her port is in keen competition with several rivals for a share in the ocean trade of the North Atlantic seaboard, with its rich hinterland and heavy export and import tonnage. Montreal, Boston, New York, Philadelphia, and Baltimore are all in the race, with physical advantages so nearly balanced that any neglect on the part of those responsible for the port's development will surely lead to a decline of traffic. Trade is conservative, and once lost it is hard to recover. New York, with its 40-foot approach channel and the advantage gained early in the competition through the Erie Canal, has won a position from which she cannot well be dislodged. A commodious harbor, steamship lines to all parts of the world and ample railways to the hinterland have secured her supremacy as the premier port of the Atlantic seaboard.

In the matter of distances there is little difference between the competitive ports under consideration. The distance from Chicago to Liverpool by the five ports varies from 3,813 miles via Montreal, to 4,153 miles via Baltimore, a difference of but 340 miles. Baltimore is the nearest to Chicago and Montreal the nearest to Liverpool. With approach channels and distances so nearly alike, and with practically equal rail connections to the hinterland, it will be readily seen that there is little to choose between Montreal, Boston, Philadelphia and Baltimore, save in the matter of port conveniences and facilities.

Montreal is an example of a systematic and logical development of a seaport made possible by the fortunate circumstance that she retained the ownership of her water front. The city not only builds and owns all the docks, but also the grain elevators and all track connections with railroad lines. A sufficient revenue is derived from switching charges, handling grain and rental of privileges to pay maintenance and operating expenses and interest on bonds, without charging the ship any wharfage. Unfortunately, the example of Montreal cannot well be followed by either Boston, Baltimore or Philadelphia, for the reason that neither city owns but a small percentage of the available water front.

The duly constituted port authorities of both Boston and Philadelphia are active in providing municipal terminals and in endeavoring to build up the business of their respective ports so far as their means will permit. Aided by a State loan of $9,000,000, the Directors of the Port of Boston have recently completed two piers, each 1,200 feet long and 300 feet wide, costing from 2½ to 3 millions of dollars each, and have voted the construction of a dry dock to cost 3 millions of dollars. A contract has been made within the year with the Hamburg-American Line for the inauguration of a high-class passenger service with large ships of the "Amerika" class, 22,622 gross tonnage, and efforts are being made looking to the establishment of regular services to the Gulf of Mexico and the West Indies. The activity of the port of Boston and the support rendered by its State may well serve as object lessons to the port of Philadelphia and the State of Pennsylvania.

Transportation in all its aspects is an exceedingly complex subject, involving not only a wide range of technical engineering, but also intricate problems of economics and finance. But to the engineer, in the first place, is due the credit for the wonderful achievements that have been attained. Overcoming all physical barriers he has linked together by sea and land the remotest corners of the earth, and has placed within reach of all the products of the world. Unfortunately, credit does not always fall where credit is due, and although the human race owes a heavy debt to the engineer for its material welfare and prosperity, the financiers and promoters are usually preferred creditors.

Colloidal Palladium as a Cure for Obesity

An excess of adipose tissue, whether due to addiction to the pleasures of the table—greediness, in plain words—or to pathological causes, such as faulty metabolism and imperfect processes of inhibition, is distressing to its victim in many ways and may be injurious to health as well as a source of personal discomfort and mortification. Hence, the methods of reduction are numerous and well exploited. Some of these, however, such as those based on restricted diet and vigorous exercise, depend on the will-power of the patient for their effectiveness, a factor which is lamentably variable and inconstant; others, including various purgatvie and sweating regimens, may seriously affect the general health; while others still, such as electric treatments, special baths and massage, may be prohibitively costly from the necessary expense of apparatus and attendants.

Such disadvantages seem to be absent from a method of reducing obesity by physico-chemical action devised by Dr. Max Kauffmann and described by him in a late number of the *Berliner Tageblatt*. It consists of the injection under the skin of a preparation of colloidal palladium, and the claim is made for it that it is effective without demanding thirsting, fasting, or dieting, and without affecting the health unfavorably. The substance named is injected under the skin in quantities of 50 to 100 milligrammes per dose, and it is alleged that the fat at once begins to dissolve and disappear at the rate of about 2 pounds per day, nearly 40 pounds having been lost in a comparatively brief time, leaving the patient's health not only uninjured, but actually improved.

The process is commented on favorably by Dr. Carl Ludwig Schleich in *Ueber Land und Meer*. He points out that the most natural method of reducing fat is to accelerate the internal combustion, or oxidation by an increased intake of oxygen, which may be accomplished by muscular labor, outdoor sports, gymnastics, breathing exercises, and so forth. The application of cold by cold baths and rubs, repeated chillings, and by the wearing of thin clothing is likewise useful, since the fat is then called on to play its natural part of fuel and is literally burned up, i. e., changed into carbon dioxide and water, in the effort to retain the body at its normal temperature.

Where an accumulation of fat is due to pathological causes, however, there is a lowered power of oxidation in the system. In some manner the delicate reactions and interactions of metabolism and inhibiting factors have been disturbed and thrown out of gear, and this forms the starting point of Dr. Kauffmann's theory.

"He justly observes that in cases of obesity the oxidizing power of the organism is disturbed and hence was led to believe that this function could be partly replaced or assisted by the introduction of a *catalyzer* between the fat and the oxygen, i. e., by bringing a chemico-physical fire-brand, so to speak, into the stores of reserve food material. This he found in the so-called colloidal palladium, which is taken into the circulation in the form of the paraffin-soluble palladious hydroxide. Dr. Schleich considers it conceivable that the palladium may have just such an oxidizing action as platinum is known to exert on the red blood corpuscles, or as fibrolysin and thiosinamine have upon the connective fibers of scar tissue, or again as arsenic exhibits in its selective power for certain tissues.

"The affinities of certain chemical substances," he remarks, "for specific components of cells has long played an important rôle in the investigation of dead cell-materials in histology for the recognition of tissue-constituents. . . . Now a new era is beginning when this property is utilized with regard to living cells."

The farther end of this road is waterbound macadam. The nearer part is bitumen-bound. Note the difference in wear.

Permanent Roads an Economic Necessity

Waste Occasioned by Poor Road-Engineering, and Excellent Results Secured by Good Practice

By Harry Wilkin Perry

Applying oil to the road by special machinery. This is common practice at the present day.

THIRTY-NINE governments sent delegates to the Third International Road Congress that met in London during the last week in June to interchange ideas on the subject of highway improvement and maintenance. There were twenty-four hundred guests at the reception of the delegates by the Lord Mayor. This indicates how great and wide spread is the interest in good roads as a necessity of the industrial, commercial and social life of to-day.

View near Chevy Chase, Md., showing seal coat application in foreground, and finished road in the distance.

View of a very good specimen of brick road construction through Reynoldsville, Pennsylvania.

As a result of a number of weighty sessions, several sets of resolutions were adopted. One set dealt with the location of main roads with relation to towns, limitation of gradients, radii of curves, location of street car tracks, fixing of building lines and control of main road planning outside of towns by some central state authority. Another set dealt with wood block pavements in cities. A third set dealt at length with bituminous roads and a fourth with paving materials for bridges.

There seems to have been a notable lack of discussion of road materials and road building methods for rural sections, and no attempt at a presentation of evidence as to the best and most economical kind of road to meet the new traffic conditions presented by the development of self-propelled vehicles. There was a general agreement that the use of bituminous or asphalt bound macadem would meet the requirements of a great range of traffic and climatic conditions, but no resolutions were passed favoring any particular kind of paving material or road making method among the many available for selection.

This has become a very acute problem in the United States, as macadam roads, both the old style water-bound road and the bituminous macadam, are proving inadequate to traffic needs. They are soon ruined by the effects of water and frost and by the mixed horse and motor vehicle traffic. It is becoming more certain every year that the only solution of the road problem is the building of roads that will be permanent.

A road problem: Snow and ice fill the ditches and water escapes down the middle of the road.

W. D. Sohier, chairman of the Massachusetts Highway Commission, in the discussion on bituminous roads at the road congress, remarked that the best roads with bituminous binding that he had seen were in England but that the road question had become more urgent in Massachussetts than in either England or France because there were more teams and motor cars in use in the American commonwealth. Spraying with light asphaltic oils had given good results for light, fast traffic, he said. A road thus treated would last four years with a traffic of 1,000 to 2,000 automobiles per day, but would fail in two months under a traffic of 300 vehicles a day carrying three tons each.

Highway traffic is undergoing a rapid change from methods in use from time immemorial. Faster and better transportation by road has become an economic necessity of expanding industry and commerce. Improved rail and water transportation must be supplemented by better methods for the collection and distribution of all kinds of commodities and merchandise. This requirement is being met by the growing use of the motor truck, motor delivery wagon, tractor and trailer and other forms of mechanical road vehicle. General use of these self-pro-

Fourteen-year-old oiled macadam road. Note its excellent condition.

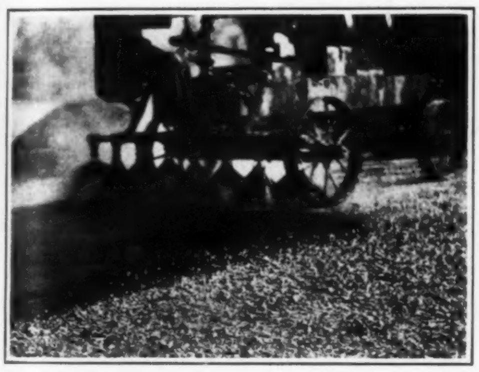
Specimen of a California road. Highway through the blossom country.

Limestone macadam road at Cannonsburg, Pa. Built in 1900. Disintegrated by water and frost.

Brick-bituminous road at Wallingford, Conn. Preparing subgrade and getting ready to lay curb.

pelled vehicles is as inevitable as was that of the mechanical seeder, planter, cultivator, reaper and binder, mower and thresher.

It is imperative that the main highways should be brought up to a standard to meet this development as rapidly as possible. To attempt to restrict loads and speeds to the present state of inadequacy and impermanency of the roads and bridges by limiting weights and speeds of motor trucks and exacting large registration fees annually to be applied to repairs of the roads is an unprogressive movement. It will not save the roads and its only effect will be to impede temporalily an ecomonic development that will benefit the whole people by hastening and cheapening collection and deliveries of all kinds of commodities, farm produce and merchandise and releasing large acreages of pasture, grain and hay now devoted to horse feed for the production of human food, thereby tending to keep down the increasing cost of living.



Hot application of heavy oil at Chevy Chase, Maryland.

Another method of applying tar to the road, Silver Springs, Maryland.

Water-bound macadam worn out by horse and motor traffic.

It is little short of a public calamity that, notwithstanding the evidences that have been accumulating for the last ten years that the old types of roads are unsuited even to present needs, the State highway authorities continue to waste the public money by building more of the same kinds. A resumé of highway work done or contracted for last year by nine of the most progressive States in the Union in highway improvement—namely, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Maryland, Ohio and California, which have State highway commissions and State aid laws, shows that, out of a total of 2,562 miles of new roads they built 658¾ miles of waterbound macadam, at an average cost of $7,765 per mile; 1,122 ½ miles of bituminous macadam, at $8,948 per mile; and 199¼ miles of gravel, at $5,796. Practically all of this is impermanent construction, although under light traffic the bituminous roads laid in Rhode Island five years ago have required very little reparing and in the opinion of the State Board of Public Roads are apparently good for five years more under the same traffic conditions.

There is no apparent good reason why really permanent roads should not be built instead of the temporary macadam roads. Necessary funds for such roads have been provided by large bond issues in a number of States; notably in New York, Pennsylvania and California. To use this money for roads that will not last more than ten years, while the bonds run for fifty years, is a suicidal policy. The public someday will surely hold the administrations of the highway departments accountable for it.

For $15,000 a mile the road commissioners of Wayne County, Michigan, of which Detroit is the county seat, are building concrete roads from 12 to 24 feet wide over the "metal", which is only one half more than New York State pays for macadam roads. The experience of the city of Bellefontaine, Ohio, proves that a concrete street will last many times as long as one of macadam, and will cost almost nothing for repairs. Twenty one years ago the city laid half a mile of concrete pavement that has cost less than $150 for repairs to the present day. The surface has worn not to exceed one half to three quarters of an inch where the horses travel, and the street is good for nobody knows how many more years of wear. Yet macadam roads laid in Bellefontaine with money raised by ten-year bonds, of which the last was paid last December, are now worn out and the council is preparing ordinances to repave with brick.

Wayne county has laid 65 miles of concrete roads and finds that the annual repairs have cost from $100 to $200, as compared with $14,000 and $16,000 spent on repairs and reconstruction of the macadam roads. Charges for repairs and reconstruction of perishable roads make them more expensive in the long run than permanent roads, and except during the first year after construction they are never so satisfactory as the permanent road. They soon become dusty and rough so that they are unpleasant to travel over or to live beside. They are unhygienic and in wet weather become muddy; more tractive effort is required at all times to haul loads over them than on the smoother, harder concrete, brick or other permanent road.

Road from New Haven to New York, sprinkled with oil once a season and sanded 2 or 3 times. 500 to 1,000 automobiles pass over this road daily.

Applying screenings in the preparation of a bituminous macadam road surface at Chevy Chase, Maryland.

In view of the urgency of the situation, it seems incomprehensible that so little endeavor has been made to ascertain the most satisfactory, durable and economical kind of road for mixed traffic of all kinds and to compile data showing the comparative cost of construction and maintenance of different kinds of roads over a long period of years. This is a work that could properly be undertaken by the Government Office of Public Roads. It would seem to be the first duty of that office to solve this question, and in fact Acting Director Paul D. Sargent, of that office, states, that scattered records of the cost of maintenance of different kinds of roads are being studied for a proposed bulletin on brick roads, and that there is now in print by his office a bulletin entitled "Repair and Maintenance of Highways" which will show these costs, where they have been placed on record, for various types of roads for a series of years.

A bulletin presenting and analyzing concisely such essential kinds of roads with a view to bringing clearly to the attention of road engineers and highway commissioners the best and most economical materials and methods for road making to meet changing traffic conditions undoubtedly would receive a most appreciative welcome.

Until satisfactory permanent roads can be provided, the policy of State highway departments and local road commissioners should be to improve the roads temporarily by graveling the more traveled ones and dragging the earth roads with split-log drags. The average cost of gravel roads in 31 States in 1909 was $2,047 per mile as compared with an average cost of $4,989 for macadam construction in 34 States. The average annual cost of dragging with split-log drags, as practiced extensively in Iowa, was $3.75 per mile.

It is worthy of particular note that California has taken the lead in permanent road building. Last year she built 104½ miles of cement-concrete roads, at an average cost of $7,326 per mile and only 19 miles of water-bound macadam at $7,463. No bituminous macadam or gravel roads were made, and the oiling of roads had been abandoned to a large extent, although the State originated the idea of oiled roads more than twelve years ago. Five and a half miles of asphalt were laid on concrete last year at a cost of $16,643 per mile and 6½ miles on macadam at a cost of $6,703, making 116 miles of permanent highway out of a total of 125 miles of new road.

There is much significance in the fact that while California ranks thirty-sixth among all the States of the Union in population per square mile, she stands seventh in miles of improved roads and streets and fourth in the number of motor trucks in use.

Three years ago the State voted a bond issue of $18,000,000 for the construction of a system of State highways. To comply with the provisions of the law, 2700 miles of State roads must be improved, and it is the present policy to construct second-class and temporary pavements on these roads. But a committee of engineers of the League of California Municipalities, appointed in 1911 to report on the work to be done, contends that standard permanent pavements should be constructed on the more important roads and the less important one simply be graded and, if necessary, improved later from the proceeds of a subsequent bond issue, S. J. Van Ornum, one of the engineers on the committee, recently wrote as follows:

"We believe that the state roads will be subjected to as heavy or heavier traffic than the majority of city streets owing to the heavy loads now being hauled by automobile trucks, and the wear and abrasion due to the fast moving automobile. Therefore, we believe that the type of paving construction adopted for state roads should be similar to that which has been found most durable for paving city streets."

Automobiles and motor trucks have been blamed so generally by legislators and other users for the widespread destruction of the roads that it is pertinent to conclude with the following quotation from Walter W. Crosby, Chief Engineer of the State Roads Commission of Maryland:

"An expression seems abroad to the effect that motor traffic is exceptionally destructive to all road surfaces, but while this may be the case generally with those surfaces designed primarily for horse-drawn traffic, it does not seem to the writer to be at all true where the surfaces were properly designed for motor traffic itself. On the contrary, in these latter cases, the worst enemy of such surfaces seems to be the shod feet of animals drawing loads; and were such traffic excluded from these roads, the maintenance costs would probably be reduced to almost nothing per anum.

"A combination of motor and animal traffic seems to create the most difficulties in the way of proper design or selection of a good road crust and to require usually the largest expense for maintenance. However, it is this combined traffic that in the far larger number of cases must be expected, and for which a solution will be required.

"The addition of the motor vehicle, with its greater radius of action, to the vehicular means of communication certainly increases the importance of having the longer main roads improved for its satisfactory use. It is obvious that smooth roads are essential.

"The susceptibility of the motor vehicle to shock from inequalities of defects in the road surfaces (even when proceeding at moderate speeds) makes necessary smoother surfaces than were acceptable to horse-drawn traffic and greater care in repairs and maintenance work. And the distribution of the road dust by the motor at last calls in a commanding way general attention to a previously existing defect of most old crusts—the existance of a condition of the surface which was unquestionably a source of serious injury to public comfort and health.

"Increase in permanency of form of construction results in decrease of maintenance expenditures, and, considering any probable increase in traffic and its resulting strains on the crust, is in many cases, therefore, likely—up to a certain point at least—to prove the more economical way in the end."

An Analysis of Glare from Paper*

By M. Luckiesh

It is well known that glare in any of its various forms diminishes the effectiveness of an illumination. Glare from polished objects has become recognized as a very serious matter. For instance, take the case of reading from glazed paper. We are able to see printed letters because of the contrast between the dark letters and the bright background. If this contrast is greatly diminished the ability to read with ease is decreased. The reflection from commercial papers is a combination of diffuse and specular reflection. The effect of the specular reflection, the source of the glare, is well illustrated by placing a clear sheet of glass over white blotting paper.

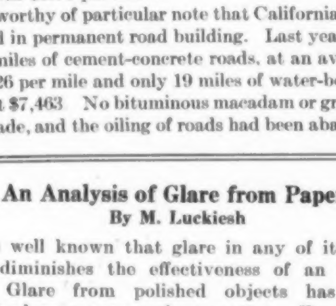


Fig. 1.—Apparatus employed in the investigation.

The type and location of the lighting unit play important parts in glare from paper. The brightness due to diffuse reflection varies approximately inversely as the square of the distance from the lighting unit, while the brightness due to specular reflection is approximately constant and depends on the intrinsic brilliancy of the unit. Obviously this annoyance due to regular reflection often disappears when the paper is held close to the lighting unit.

THEORETICAL CONSIDERATIONS.

The following numerical example further illustrates how the ability to read is influenced by specular reflection from glazed paper and ink. Assume a perfectly matt, white paper with matt black letters upon it, with brightnesses of 100 units and 1 unit for the paper and the letters, respectively. The contrast ratio in this case will be 1/100. Now, assume a white paper with black characters upon it, neither of which is matt, but for which the "contrast ratio" due to diffusely reflected light under certain conditions is also 1/100. With the paper in a certain position, light will be regularly reflected from it to the eye. Assume that under the same conditions the brightnesses of the letters and paper due to specular reflection alone are each 100 units. These brightnesses are superposed on the diffuse brightnesses and we have a "contrast ratio."

$$1+100 : 100+100 \text{ or } 101/200.$$

Obviously the ability to read has been greatly reduced even without considering the possible reduction in visual efficiency due to the contraction of the pupil, scattered light in the eye, and other attendant influences. In many cases the specular reflection from the ink is considerably greater than that from the paper, owing partly to the fact that the pressure of the type has made the surface glossy. In such case the "contrast ratio" will approach and often exceed unity. When it equals unity, obviously it is impossible to read. When it exceeds unity, the letters are brighter than the background.

METHOD AND RESULTS.

An arrangement for measuring the distribution of brightness across the "glare spot" on the paper under ordinary conditions is shown in Fig. 1. By means of the photometer the brightness of a spot at *b* was measured as the paper *a* was tilted, the position of the paper as shown being taken as zero angle. A moderately glazed paper was used.

The results obtained were usually plotted to the same maximum value. Fig. 2 shows the different results for a bowl frosted and a clear tungsten lamp at a height of 16 inches. In Fig. 3 are shown the results under direct and indirect systems of lighting. The height of the direct unit was 8 feet. In the case of the indirect lighting, the ceiling was 10 feet from the paper. Owing to the arrangement of the apparatus, the angle of regular reflection is at 45 degrees. It is seen that at this angle the brightness of the paper is considerably influenced by specular reflection in all cases excepting where the light-giving area is large. The advantage of a light-source of large area in decreasing glare is evident.

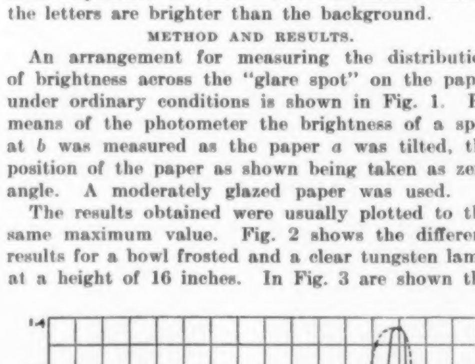


Fig. 2.—Brightness of the paper at various positions when illuminated by bare lamps at a height of 16 inches. A, bowl frosted; B, clear.

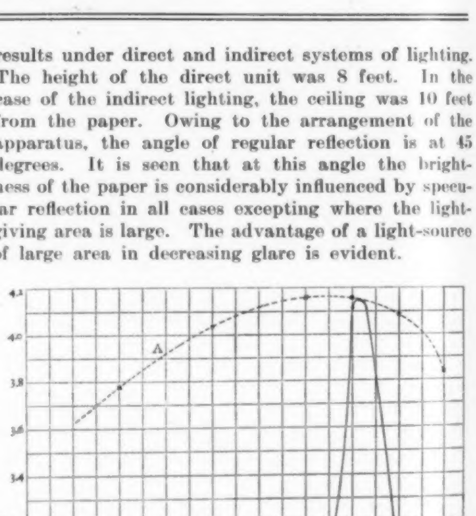


Fig. 3.—Brightness of the paper at various positions under direct and indirect lighting. Height of direct unit 8 feet. A, indirect; B, direct.

CONCLUSIONS.

Sources of low intrinsic brightness are desirable from the standpoint of glare from paper. When the unit is not close to the paper there seemed to be little practical difference between the direct units examined. With indirect lighting the glare from paper is much less than with direct lighting.

When the reader is free to change his position or that of his paper the system of lighting is of considerably less importance, but it becomes of great moment when glare from paper cannot be avoided owing to the fixed position of the work.

For desk lighting where the unit is not far from the work, reflectors with large diffusing surfaces produce less annoyance from glare than a mirrored reflector. A satisfactory desk unit is made by placing an opal glass in the opening of an opaque reflector.

*Reproduced from the *Electrical Review* and *Western Electrician*.

Blunders Made by Nature*

The Part Played by Nature in Causing Disease of the Respiratory Tract and Circulation

By Augustus Maverick, M.D.

THE RESPIRATORY TRACT.

The nose is so full of natural defects that it keeps many a specialist fat and prosperous. Numerous people are born with an unusually high palate which pressing up on the nasal septum pushes this to one side, causing interference with breathing and a tendency to chronic catarrh. Spurs of bone and enlarged turbinates, not due to disease or injury, are likewise frequent and cause much trouble. The ease with which the virus of meningitis and infantile paralysis can enter the skull through the roof of the nose has been pointed out; likewise the danger of the Eustachian tube in carrying infection from the upper air passages to the inner ear and brain. The nose was once thought to be more of an ornament than anything else, but later physiologists discovered that it served to heat the air passing to the lungs and filter it of dust and bacteria. When nature, however, gave the nose the ability to catch all uninvited germs it did not tell the nose what to do with these germs, and thus, while the lungs are kept free from many dangerous bacteria, these swarm in the upper air passages and cause much mischief. It does not make much difference to the bacteria themselves that nature should limit them to one field, since judging by the large number of diseases which they cause in the nose and throat they are perfectly contented where they are. Neither does it make much difference to ourselves, for while the filter action of the upper air passages lessens the frequency of disease in our lungs, the inability of nature to handle the bacteria which collect above predisposes us to acute "colds" of all kinds, hay fever, diphtheria, epidemic meningitis, infantile paralysis, influenza, glanders, leprosy, scarlet fever, mumps, measles, rubella, and other infections we are not so sure about. Surely if we had no nose and all the bacteria passed down into the lower air passages, we could hardly have a choicer variety of diseases than those mentioned. The worst part of it all is that the nose is by no means a perfect filter; although it stops enough bacteria to cause a number of infectious diseases, it still permits enough to pass to be responsible for consumption, pneumonia, whooping-cough, pneumonic plague, pulmonary anthrax, lung abscess, and purulent bronchitis; tuberculosis and pneumonia, as we know, are the two commonest causes of death. The lungs of persons working in a very smoky atmosphere or who handle coal a great deal soon become black with coal dust; this shows that the nose allows plenty of dust to pass as well as germ life. General anesthesia, with the use of ether or chloroform, is sometimes followed by pneumonia, caused by bacteria passing down from the upper air passages. In cases of this kind when an individual is unconscious with his general vitality lowered, the danger of infection reaching the lungs from above is great. Unwilling to trust the upper air passages any longer, certain surgeons have recently administered their ether through a rubber tube passed directly into the wind pipe in order to sidetrack the nose and throat. From results obtained in many patients, besides large numbers of animals, they report much less frequent undesired after effects than by the usual method.' There were no pulmonary, bronchial, or laryngeal complications; postoperative vomiting was rare and the general depression common after anesthesia, especially in the aged, was much less frequent; furthermore, the danger of vomited material passing into the lungs was done away with. If the nose is a great filter this does not look like it. Although it is better to breathe through the nose than the mouth, this is not because the nose is ideal but because the mouth is merely worse.

Passing down from the nasopharynx to the larynx and trachea, the most glaring defect which attracts our attention is that the windpipe is placed in front of the gullet instead of behind it. All food and drink leaving the mouth en route to the gullet must pass over the entrance to the windpipe. The frequency with which food goes into the wrong pipe is illustrated daily, but the greater frequency with which minute particles laden with bacteria find their way into the air-tube passes unnoticed, although a constant menace to our lungs. If the windpipe were behind the gullet with a ridge between the two it would not only be free from the danger of contamination but it would be a great convenience; we could swallow and breathe both at the same time and would not have to be pounded on the back by some misguided friend who in an effort to dislodge a piece of chicken from our ventilator sends it further down into regions below. Another good reason for desiring our windpipe behind the gullet is because its present position is too exposed to injury from without. We can live with our gullet shut off long enough to have it repaired, but when the five fingers of some disagreeable assassin close on our windpipe our future is sadly marred. The ease and importance of closing the windpipe is known to all animals, and every good dog fight comes to a sudden end when the teeth of the victor settle about the trachea of the victim. If nature insisted on placing not only the windpipe but numerous other vital structures in the neck with such free exposure it seems fair that we should have at least a number of little ribs around our neck with a plate of bone in front like the chest in order to protect them. The epiglottis which is hinged above the entrance to the larynx is practically a useless structure; it is intended to close like a lid over the larynx and keep food from entering; but the constrictor muscles of the glottis and not the epiglottis close the windpipe during the act of swallowing. The epiglottis merely stands in the way to catch debris like a snag in a river.

In relation to the great importance of its function the windpipe is too narrow; this pertains especially to the upper orifice or glottis. The walls of the glottis are soft and vascular, and it does not take much to cause them to swell shut and prevent air from entering. A whiff of ammonia or even a drink of strong whiskey may shut them tight, and in our efforts to breathe the muscles of the glottis go into a spasm and close the orifice tighter still; it might be a matter of only a minute or so before the swelling goes down, but a minute seems like a century on such occasions. In children the stream of air enters such a fine passage that it is a wonder they get enough. It takes only a little catarrh to close their glottis and then comes the gasping for breath, the convulsive movements, the cyanosed face, and the distress incident to croup.

Shortness of breath in many respiratory affections becomes a serious symptom. One reason why we do not get enough air in emergencies is because when we take a breath much of the air does not reach the lungs but passes only as far as the upper air passages, the trachea and larger bronchial tubes, where it becomes mixed with the stagnant air which always lingers in these parts. Only a small proportion of the air in the lungs comes in direct at each inspiration from the atmosphere and only a small proportion escapes into the atmosphere at each expiration. After several breaths all the air first breathed reaches the lung chambers but only after it has become much diluted with stale air, while the air last breathed is undergoing the same stages of dilution. Thus, as a matter of fact, the lungs never get a taste of real fresh air. There is, of course, some value in allowing the air time to become warm and less irritating to the lung air sacs, but when we are short of breath it only makes matters worse to keep breathing much of the same air over and over. Many functions of the body have a residual power ready for emergency, but the respiration when embarrassed can do little or nothing to help itself and must depend upon the enlargement of the heart in order to get its "second wind."

The lungs coming at a later stage of animal history were not made with the same skill and care that was used on other organs. They are really unfinished structures and for this reason a weak point for attracting disease. Thus, it depends largely on the lungs of newborn infants whether they are to live or not, and it is the lungs of the aged that usually play them false in the end. Diseases of the lungs, tuberculosis and pneumonia, always head the death list and chiefly because nature has not given the lungs the proper protection. Unsatisfied with making our lungs weak in the first place, nature is still using them as a target for its practical jokes. Thus, there is a natural tendency for the human trunk to become shorter with a corresponding degeneration of the first rib. As Wiederscheim pointed out this produces a tendency to degeneration of the lung apex and helps explain the great frequency with which tuberculosis arises at this point. Some people in their eagerness to blame corsets for all troubles of the chest lose sight of the natural weakness of the lungs. Corsets, in fact, are often a benefit to young women in preventing tuberculosis, since by compressing the lower part of the lungs they encourage greater respiration in the spaces where tuberculosis usually begins.

THE CIRCULATION.

The heart handles all the blood in the body and is the distributor to which all other organs look for food. Having such absolute control over the body fluid it would be thought should any organ suffer from starvation it would hardly be the heart. This is not the case, however, since the heart will often starve itself while vigorously supplying other organs. It does not do so from any philanthropic motive but because of its natural makeup. In the heart of lower animals like the frog the blood within the heart chambers soaks through and nourishes the muscular walls, but in the human heart the inner lining prevents this; instead there is a separate set of arteries branching off just above the aortic opening. This spot was unwisely chosen by nature for it is here that the first signs of old age and arterial wear often set in with the accompanying overgrowth of fibrous tissue and plates of lime which tend to plug the portals of the heart's food canals. Thus, the heart may bathe in blood without a drop to drink, while the unfortunate owner experiences all the agony of angina pectoris.

Nature's failure to complete the construction of the heart at birth is not very rarely the cause of disease. We are all familiar with the "blue baby" in which the fetal aperture between the two sides of the heart remains open after birth. Other congenital defects are less frequent but the possibilities are many. Wonder is often expressed that the heart can work steadily without rest. As a matter of fact the heart ventricles not only rest between beats but while the auricles are active as well; that is to say they are working three eighths of the time or 9 hours in 24. The auricles only work one eighth of each heart circle or 3 hours out of 24. Certainly this is not a remarkable showing for a pump.

In a former article[1] the part played by the end arteries in nature's treatment of disease was mentioned. It certainly was a great advantage to us when nature allowed the ends of many of our arteries to freely intercommunicate so that when one branch becomes plugged another can carry on the blood flow. In many of the chief organs nature failed to do this and the result of this abrupt termination of the blood channels causes much mischief. Thus, if one of the end arteries in the kidney or heart becomes occluded the area it supplies with blood turns into a lifeless plug. In the brain this is a very serious matter, since each little spot is so important and a plugged artery spells apoplexy; if the blood supply of the brain was properly arranged, with free arterial anastomosis, apoplexy from occluded vessels would not occur.

Arteries running along the surfaces of bone are often placed by nature in bony archways for greater protection. This is not such a benefit as at first appears since it predisposes the artery to rupture when the bone is broken, much more frequently than if the artery ran free. Thus, within the skull the middle meningeal artery runs along a groove in the bone which often overlaps the artery. There is no sense in such protection inside of the skull; in fact, it is often the cause of serious hemorrhage. A blow over the side of the head sufficient to crack the bone frequently ruptures the middle meningeal artery because the artery is fastened to the bone.

The most conspicuous natural defect responsible for disease of veins is the commonest of varicosities. Varicose veins would be rare or unknown had nature given the veins proper outside support and supplied sufficient valves. We still have valves in the veins which encircle our chest, no longer of any use since we began walking on two legs, but in the lower part of our body nature gave us altogether too few and too weak valves when it allowed us to take the erect posture. Sometimes people have piles, varicocele, and enlarged veins in the

* Reproduced from the *Medical Record*.

[1] See Scientific American Supplement, November 23rd 1912, page 330.

legs from no other cause than a natural incompetency of the valves or lack of outside support to the vessels; in other cases it needs only a little straining, prolonged standing, constipation, or the natural congestion of pregnancy to start the trouble. The greater frequency of congestive disorders of the left ovary is, as we know, caused by the common absence of a valve where the left ovarian vein runs into the left renal, thus allowing the blood more readily to back up and stagnate than in the right ovarian vein which is supplied with a terminal valve at its opening in the inferior vena cava. The greater frequency of varicocele of the left testicle has a similar explanation. We also know that thrombophlebitis is much more common in the left thigh because of defective natural architecture. The right common iliac artery crosses the left common iliac vein and compresses it against the spine; the left external iliac vein is then crossed by the left internal iliac artery at a right angle; and finally, there is the greater length of the left iliac vessels and the pressure of the loaded sigmoid bowel on the left side which play a part in making the return of venous blood from the thigh more difficult.

Kinetic Effects of Crowds*

The Forces Due to Movements of Live Load

By C. J. Tilden, Assoc. M. Am. Soc. C.E.

For nearly a century the accepted value for the weight of a dense crowd of people has been about 100 pounds per square foot, conservative designers often assuming a slightly higher figure, and their more daring brethren a considerably lower one. The investigations of Stoney, Kernot and others, long ago showed that this was by no means the maximum value, and the elaborate work of Johnson, published in 1904, showed that an intensity of 183 pounds per square foot was within the range of possibility. The effect of Johnson's investigations was to raise slightly the load intensities prescribed by some specifications, but this effect was by no means general.

Fig. 1.—Method of determining the kinetic effect of suddenly rising from crouching position.

Thus far, the purely static effect of a crowd is the only one that has received careful study by engineers, and the "dead weight" is the loading assumed. The fact that this is not sufficient in considering the load that may come on a bridge or other structure was recognized by Robert Stevenson in the early part of the last century. In his paper entitled "An Account of Suspension Bridges," published in 1821, is the following interesting paragraph:

"But the effect we have to provide against in bridges of suspension, is not merely what is technically termed dead weight. A more powerful agent exists in the sudden impulses, or jerking motion of the load, ... The greatest trial, for example, which the timber bridge at Montrose, about 500 feet in extent, has been considered to withstand, is the passing of a regiment on foot, marching in regular time. A troop of cavalry, on the contrary, does not produce corresponding effects, owing to the irregular step of the horses. The same observations apply to a crowd of persons walking promiscuously, or a drove of cattle, . . ."

Stevenson, however, does not suggest any definite values for this "more powerful agent," which he recognizes and describes with such clear appreciation.

Shortly after Johnson's paper was published, a letter, signed by Mr. R. Moreland, appeared in London *Engineering*, in which a suggestive experiment was reported:

"In 1900 my firm had a contract for the Manchester Racecourse for some large stands, and to gain information we put as many men as possible on our 10-ton weight-bridge, and we found that we could get ninety men as close as possible into a space 14 feet by 8 feet, or 112 square feet, and they weighed 115 cwt. 1 qr., which would equal 1 cwt. per square foot. We then asked them to jump, and the load went up to $1\frac{1}{2}$ cwt.; they then ran, four abreast, across the machine, but no excess was recorded over the $1\frac{1}{2}$ cwt. per square foot."

Details of this experiment are meager, but it is the only one, so far as the writer is aware, in which a determination is sought of the increased load effect due to motion in a group of human beings. In general, in structural work at least, this increase is assumed to be cared for by the "factor of safety," that pernicious and misnamed offspring of ignorance.

The study of kinetic effect is far more complex than that of static effect, for the movements of a crowd of people may take place in infinite variety, and each change of motion must be accompanied by some exertion of force other than the purely static condition. The problems suggested, therefore, are capable, at best, of only approximate solution. The following study is an attempt to throw some light on the question of determining and analyzing as far as possible the forces exerted by an individual under certain simple conditions of motion. The extent to which such observations apply to crowds, and the limitations of such an application are then considered.

The subject is divided naturally into two parts: First, the vertical effect, as in the experiment described by Moreland and quoted above, manifested as an increase over the static or dead load; and, secondly, the horizontal effect which appears as a lateral force. The first is due to changes of motion in a vertical direction, the second to similar changes in a horizontal direction. The experiments described are simple and direct, and though the results may not be scientifically exact, they are at least instructive, and furnish a basis for modifying somewhat our views on the possible effect of crowds.

Vertical Effect: I. Rising Suddenly from a Crouching Posture.—In this experiment the subject was asked to assume a crouching position, as shown by Fig. 1, on an ordinary platform scale. His weight was determined and recorded. The counterpoise was then moved out on the scale-beam until it registered a load 40 or 50 pounds in excess of the static load, the hooked end of the scale-beam resting,

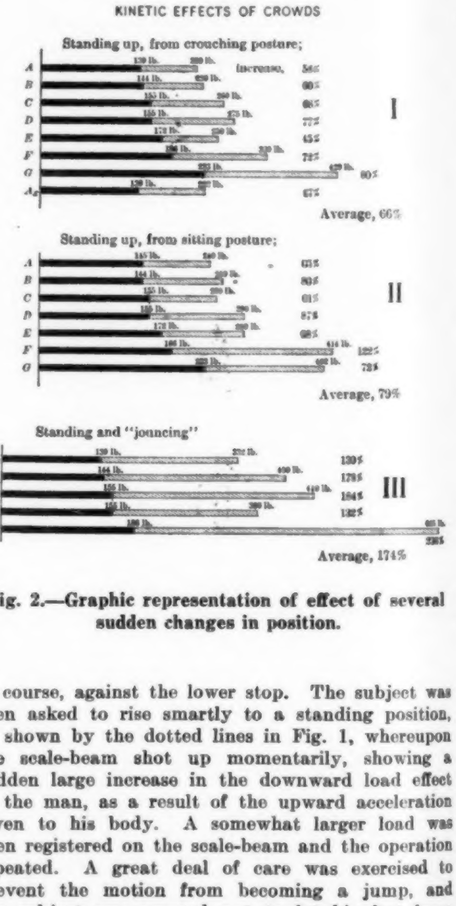
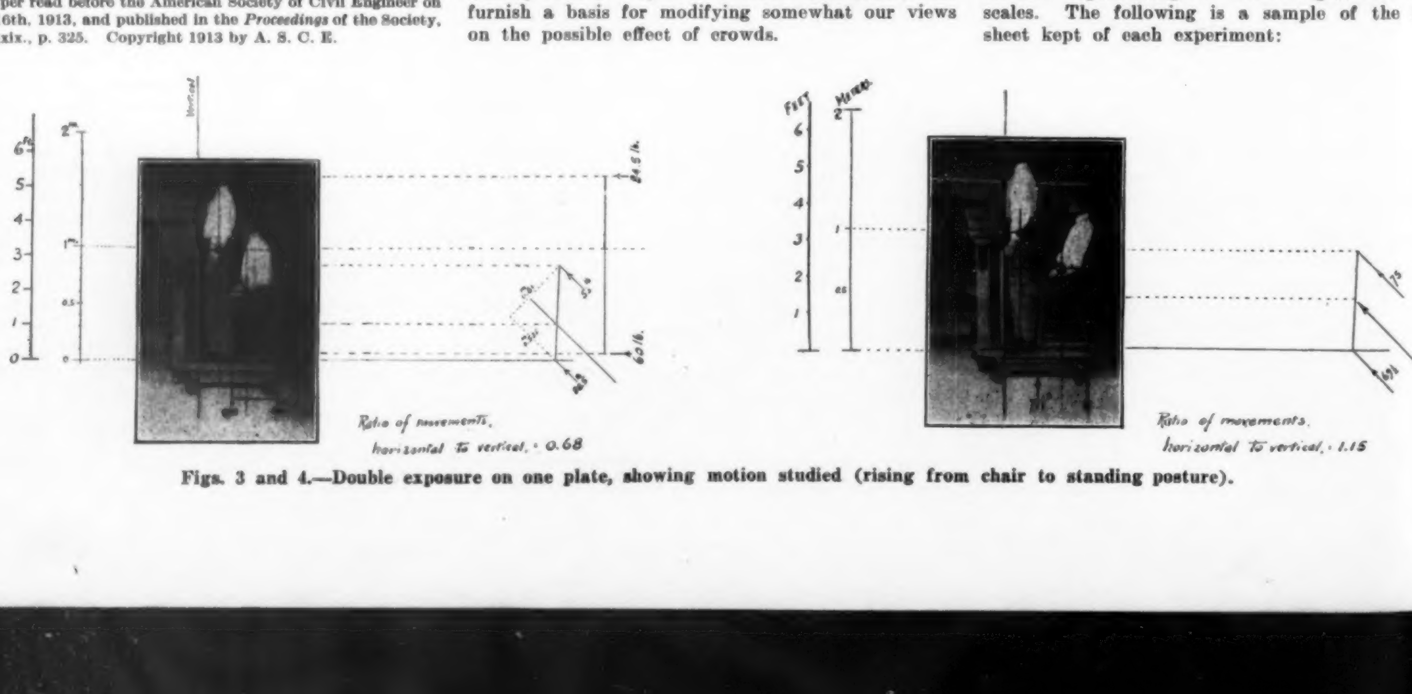


Fig. 2.—Graphic representation of effect of several sudden changes in position.

of course, against the lower stop. The subject was then asked to rise smartly to a standing position, as shown by the dotted lines in Fig. 1, whereupon the scale-beam shot up momentarily, showing a sudden large increase in the downward load effect of the man, as a result of the upward acceleration given to his body. A somewhat larger load was then registered on the scale-beam and the operation repeated. A great deal of care was exercised to prevent the motion from becoming a jump, and the subject was warned not to let his feet leave the platform. The movement was smart and quick, however, occupying, perhaps, one third or one fourth second. Each repetition of the movement was recorded, and the words "Raised" or "Not raised," referring to the scale-beam, were written after the number representing the load registered on the scales. The following is a sample of the record sheet kept of each experiment:

* Paper read before the American Society of Civil Engineer on April 16th, 1913, and published in the *Proceedings* of the Society, vol. xxxix., p. 325. Copyright 1913 by A. S. C. E.



Figs. 3 and 4.—Double exposure on one plate, showing motion studied (rising from chair to standing posture).

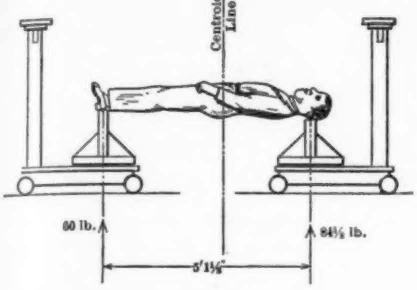


Fig. 5.—Determining center of gravity of body in stretched out posture.

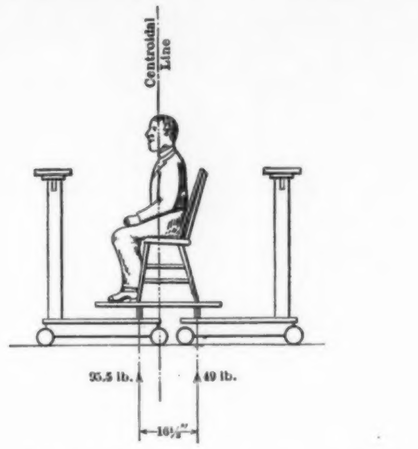


Fig. 6.—Determining center of gravity of sitting person.

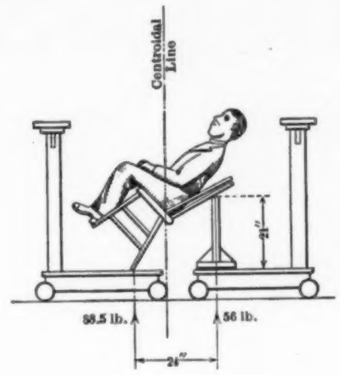


Fig. 7.—Obtaining the second centroidal line for a sitting person.

(Name of subject.) Static weight = 155 lb. (Date.)

Scales set at	220 lb.	Raised.
" " "	240 "	Raised.
" " "	260 "	Barely raised?
" " "	260 "	Raised.
" " "	265 "	Raised.
" " "	270 "	Raised.
" " "	275 "	Not raised.
" " "	275 "	Raised.
" " "	280 "	?
" " "	280 "	Not raised.
" " "	280 "	Barely raised?

It is seen that this man, weighing 155 pounds, exerted a momentary downward pressure of 275 pounds, as shown by the scale-beam lifting from the stop, as a result of the movement described. As there was some question, even after three trials, as to whether 280 pounds had been exerted, the figure taken was 275 pounds or an increase of 77 per cent over the static load. (See Line D, Fig. 2, I.) Eight experiments of this sort were tried on seven different men, weighing from 139 to 233 pounds. The results are shown graphically by Fig. 2, I, in which the black portion of each line represents the static weight and the shaded portion the increase due to rising suddenly from a crouching position. It is interesting to note that the greatest increase recorded, 80 per cent, occurs for the heaviest man *G*, a former tennis champion, who is very active on his feet.

The two lines marked *A* and A_x, one showing 58 per cent and the other 67 per cent, are for the same man. The result shown at *A* was obtained in the usual way, as illustrated by Fig. 1 and previously described. The case, A_x, differed from *A* in that a timber, about 11 inches deep and weighing 108 pounds, was put on the scale platform on which the subject stood. While it is not likely that the interposition of this heavy mass had anything to do with the slight increase (from 58 to 67 per cent) shown in A_x, it obviously did not tend to diminish the kinetic effect.

II. Rising Suddenly from a Sitting Position.—This experiment was similar to I, and was conducted in the same manner, the only difference being that the subject rose suddenly from the chair in which he was seated, instead of getting up from a crouching position. The movement is indicated clearly by the photographs, Figs. 3 and 4, in which the two successive positions of the subject are shown by a double exposure of the negative. The records were made in precisely the same manner as for Experiment I, with the results as shown in Fig. 2, II. The letters *A*, *B*, *C*, etc., refer to the same individuals as in I.

It is interesting to note that this movement, which may readily occur in a theater, grandstand, or other place where a large audience is gathered, gives distinctly higher values than are found in Experiment I, the average increase being nearly 80 per cent, and no individual case, of the seven recorded, falling below 60 per cent.

III. Jouncing.—In this experiment, the results of which are shown by III, Fig. 2, an attempt was made to get an approach to a maximum individual effect. The subject, standing on the scale platform, suddenly bent the knees and as quickly straightened them again, at the same time jerking the arms and shoulders downward to intensify the effort exerted. The instructions were to get as vigorous a movement as possible without letting the feet leave the scale platform. The vertical movement of the body did not probably exceed 2 or 3 inches. The experiment is interesting and suggestive, but hardly of much importance, as the time during which the greatest effort acts is necessarily exceedingly short. The effort is more in the nature of a quick blow. Its bearing in relation to I and II will be discussed later.

Horizontal Effect: I. Some idea of the horizontal effort exerted in Experiment II (rising from a sitting posture) may be obtained by studying the movement of the center of gravity of the subject (Figs. 3 and 4.) If the ratio of the movements, horizontal to vertical, is taken as measuring approximately the relative intensities of the respective forces, it gives a fairly good indication of the backward shove exerted by a man when he jumps up to cheer a spectacular play on the football field, or to shout welcome to his political favorite. In Fig. 3, the movement shown is from an erect sitting posture to a standing position, while Fig. 4 shows a similar movement from a less alert sitting position. The first movement is probably more nearly typical than the second, but, in jumping up suddenly, as in Fig. 3, in his final standing position a man would probably lean forward more than that shown in the photograph, so that a ratio of horizontal to vertical motion of about 0.75 might fairly be assumed. Although this ratio of movements may not show the relative force values exactly, owing to complexities of motion not taken into account in the simple geometry of the figure, it is undoubtedly fairly indicative. On such a basis, taking the increase in vertical effect at about two thirds of the static weight, it appears that, in rising suddenly from his seat, a man may exert a backward horizontal shove about one half as great as his weight, say from 70 to 80 pounds for an ordinary man.

Figs. 5, 6 and 7 are introduced to show the method of determining the centers of gravity of the standing and sitting figures. For the standing figure,

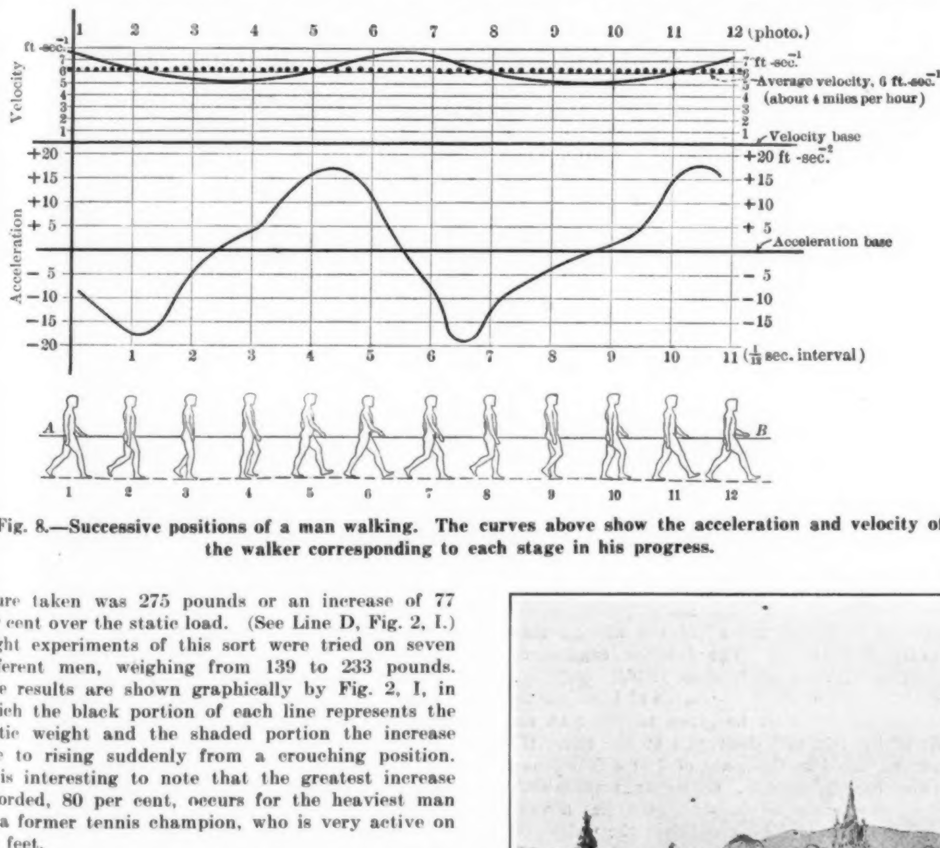


Fig. 8.—Successive positions of a man walking. The curves above show the acceleration and velocity of the walker corresponding to each stage in his progress.

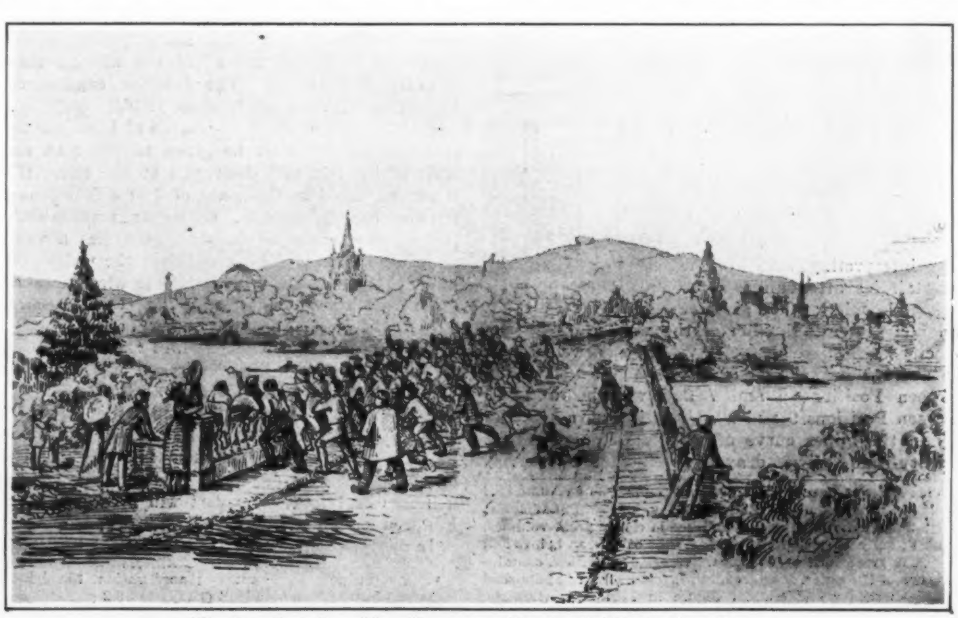


Fig. 9.—Crowd rushing from one side of a bridge to the other.

Figs. 3 and 4, the vertical centroidal line was readily drawn on the photograph by eye. The position of the horizontal centroidal line was then determined as in Fig. 5, by getting the reactions at head and heels on the two platform scales when the man was stretched out horizontally. A simple proportion between the two observed scale-weights then serves to fix the position of the line, and this is transferred to the photographs, Figs. 3 and 4, by the construction shown at the right of the figures. Similarly, for the sitting figure, a vertical centroidal line was obtained by the method shown in Fig. 6, and an inclined centroidal line as in Fig. 7, the angle of inclination of the latter being determined by the two measurements, 24 inches horizontal and 21 inches vertical, shown in the sketch. The intersection of these two lines, when properly transferred to the sitting figure in the photograph (geometrical construction on the right), locates the center of gravity of the seated man. The scale for the photographs was fixed by the two meter sticks seen clearly in Figs. 3 and 4, one laid horizontally on the scale platform between the feet of the subject and the other standing vertically in the same plane. The vertical and horizontal components of the movement of the center of gravity were then measured directly on the photograph with this scale.

II. Horizontal Forces Exerted by a Man Walking.—The motion of a man who is walking on a level floor, sidewalk, etc., at ordinary speed, is not perfectly uniform. The changes in velocity, whether acceleration or retardation, must be accompanied by some manifestation of horizontal force, this force urging the man forward when his velocity is being increased, and holding him back when it is being diminished. As these forces act on the man, his action (or reaction) on the floor must be equal and opposite to them; therefore, he will exert a backward horizontal push when his speed is increasing and a forward horizontal thrust when that speed is, for the moment, partly checked. The investigation which is summarized in Fig. 8, is an attempt to determine approximately what values these momentary forward and backward forces have.

The twelve figures shown in the lower half of Fig. 8 were traced from a series of photographs, taken at intervals of one twelfth second, of an athlete walking.[1] The man walked directly in front of and parallel to a screen which was marked off by horizontal and vertical lines into squares of 5 centimeters on a side. The subject was about 30 inches in front of this background, and the camera some 50 feet from the subject, so that the distance interval covered in each interval of time might be determined with a close degree of approximation by counting the squares passed over by the man in each successive position. In making this count, the horizontal line, *AB* was chosen as the base, as it passes very close to the center of gravity of the man for all positions, and the "reading" on the background squares was made at the intersection of this line with the buttocks of the naked figure. The total interval found in this way, from the first to the twelfth figure, was nearly 0.7 meter, or about 5.5 feet, giving an average velocity of 6 feet per second (a trifle more than 4 miles per hour) for the complete stride shown in the diagram. The average velocity during each interval (one twelfth second) of time may also be determined, and this has been done in the last column of Table 1.

TABLE I.

Photographs.	Reading off background, in meters.	Distance Interval: Meter.	Distance Interval: Foot.	Velocity during interval, in feet per second
1	0.18	0.18	0.59	7.1
2	0.35	0.14	0.46	5.5
3	0.50	0.12	0.39	4.7
4	0.62	0.15	0.49	5.9
5	0.77	0.15	0.49	5.9
6	0.92	0.20	0.65	7.8
7	1.12	0.16	0.52	6.4
8	1.26	0.14	0.46	5.5
9	1.42	0.13	0.43	5.2
10	1.55	0.13	0.42	5.2
11	1.68	0.17	0.56	6.7
12	1.85	....	....	....

In interpreting and applying these results, the uncertainties attendant on their computation must be kept in mind; they give, however, an interesting and instructive indication of the way in which the velocity varies. Thus, the velocity is well below the average between Positions 3 and 4, well above between Positions 6 and 7 and well below again between Positions 9 and 10. This is shown graphically in the upper curve of Fig. 8, which gives the velocity-time curve drawn as indicated by the computed values, not exactly through the plotted points but "smoothed out" to give an even, continuous curve. The average velocity for the stride is shown by the heavy dotted line.

To measure the force exerted, it is necessary to know the acceleration, and this is obtained by differentiating graphically the velocity curve. This acceleration curve, or "first-derived" of the velocity curve, is shown immediately below the latter. The ordinates of the acceleration curve were obtained by actual geometric construction for the slope of the tangent to the velocity curve at a number of points. It is seen that the high and low points of this acceleration curve have values, plus and minus, respectively, of 16 or 18 feet per second, which would correspond to a horizontal accelerating or retarding force of 80 or 90 pounds for a man weighing about 160 pounds.[2] These force values urge the man forward for the high points of the curve, and backward for the low points; note, in this connection, the backward shove or kick of the right foot in Positions 5 and 6 and of the left foot in Positions 11 and 12, and the forward thrust, retarding the body's motion, of the right foot in Positions 1 and 2 and of the left foot in Positions 7 and 8. Although these forces are impulsive in their nature and act for only a fraction of a second, there seems to be no doubt of their existence, and although the amount is not determinable exactly (varying as it must with different individuals and conditions), it may, apparently, equal or even exceed half the static weight of the man.

III. Horizontal Forces Exerted by a Man Running Across a Bridge.—Approaching from a slightly different viewpoint this problem of horizontal force exerted, some experimental data were collected bearing on the lateral effect which may be produced on a bridge. At the time of a boatrace, river pageant, or similar exhibition, a crowd of people will naturally gather on a bridge, ranging themselves along one side. As the spectacle moves under the bridge, the entire crowd will cross to the other side (Fig. 9) and the motion is likely to be fairly rapid. What effect has it on the structure?

As in the previous cases, the experimenting was on an individual. The observer, with a stop-watch, noted the time of the subject as he turned from the rail on one side of the bridge and ran quickly to the other. This time included the start from rest at one rail and coming to rest again at the other. The suggestion was made that the subject imagine he was watching an exciting boat race, and did not want to miss any of it as the contestants pulled under the bridge. The tests were carried out on three bridges, in three different localities, the widths between rails being 17, 49½ and 68 feet, respectively, the second and third bridges having sidewalks on both sides. Three men took part as subjects, one a vigorous active man of sixty-seven, weighing 160 pounds, another, thirty-nine years old, and weighing about 140 pounds, and the third, twenty-six years old, and weighing 144 pounds. The results are given in Table 2, and show, as might be expected, the higher average velocities for the wider bridges.

Remembering that these figures for the velocity are average values and not the maximum, we may obtain an approximation to the horizontal force exerted by the man, first, as he started on his journey across the bridge, and, secondly, when he stopped at the other side. Take, for example, the second bridge noted in Table 2 and the first experiment. The maximum speed may be safely assumed as about 12 feet per second, more, probably, rather than less, and the "mass" of the moving man at 5 units ($160 \div g$). The familiar expression for kinetic energy, $\frac{1}{2} MV^2$, then yields,

$\frac{1}{2} \times 5 \times 144 = 360$ foot-pounds of kinetic energy,

and this energy must be given to the man at the start of his trip and destroyed at the end. If this is accomplished in the space of 2 or 3 feet (one fifth to one fourth second), as seems reasonable, the impulsive starting or stopping, force has a value of about 150 pounds, nearly equal to the weight of the man. If it takes a longer time to attain the maximum velocity from the standing start—say, about one half second—the effort may be extended over a distance of 5 or 6 feet, and will amount to perhaps 60 or 70 pounds. This effort, of course, must be exerted both at the start and at the finish, as the start is from rest and the subject comes to rest again at the opposite rail. If, as may happen when he brings up sharply against the rail, the whole amount of kinetic energy is destroyed in a space of 6 inches or 1 foot, the effort will amount to several hundred pounds.

In applying these experimental results to determine the probable effect of crowds, several points must receive careful consideration. In the first place, the object of the whole inquiry is to get some sort of answer to the question: Against what loads, horizontal and vertical, should an engineer design a structure which is likely to have to carry a dense crowd of human beings? It is with respect to their bearing on this question that the experiment will be discussed.

TABLE II.

Width of bridge, in feet.	Weight of subject, in pounds.	Time of running across bridge, in seconds.	Average velocity for one trip, in feet per second.
17	144	1.6 (down-stream)	10.6
		1.4 (up-stream)	12.1
		1.6 (down-stream)	10.6
		1.6 (up-stream)	10.6
		Average......	11 ft-sec.[-1]
17	160	1.4 (up-stream)	12.1
		1.6 (down-stream)	10.6
		1.8 (up-stream)	9.4
		1.6 (down-stream)	10.6
		Average......	10.7 ft-sec.[-1]
49.5	160	4.6 (up-stream)	10.8
		4.4 (down-stream)	11.2
		Average......	10.8 ft-sec.[-1]
49.5	140	4.0 (up-stream)	12.3
		4.4 (down-stream)	11.2
		Average......	11.8 ft-sec.[-1]
68	160	6.0 (up-stream)	11.3
		5.4 (down-stream)	12.6
		Average......	12 ft-sec.[-1]
68	140	5.2 (up-stream)	13.1
		4.8 (down-stream)	14.2
		Average......	13.7 ft-sec.[-1]

Direct multiplication of individual effect by the probable number of units in the crowd is, of course, wrong. In the first place, the forces exerted are impulsive in their nature, being exerted for only a small, though finite and measurable fraction of a second. In order to get the full effect of such impulsive efforts from a crowd of people, it is necessary to have perfect synchronism of motion in every individual, a condition practically out of the question. Further, the denser a throng of people, the more individual motion is restricted, so that in the more closely packed crowds, giving the higher static loads per square foot, the increase resulting from kinetic effect is much reduced. On the other hand, that the static load only shall operate, perfect quiescence must be secured, a condition quite as impossible in any crowd as that of absolute synchronism in movement; and the duty of the engineer is to provide in every case for the maximum possible load-effect to which his structure may be subjected, a duty which is immeasurably emphasized when the safety of human beings is at stake.

The first experiment—that of rising from a crouching position—although suggestive and interesting, hardly has a practical bearing. That particular form of motion could take place only in a sparse crowd, and even then would be highly improbable. Its main value lies in showing rather strikingly the importance of some consideration of kinetic effect.

The case of a man rising suddenly from his seat, however, is of considerable importance. No one who has watched a grandstand full of enthusiastic football "fans" can doubt that a spectacular play may bring nine tenths of them to their feet with such a close approximation to unanimity of motion that the total kinetic effect must be considerable. However, if the usual allowance of 3 square feet per sitting is made, and each spectator is assumed to weigh 165 pounds or 55 pounds per square foot over the whole structure, an increase of 65 or 70 per cent (over the 55 pounds per square feet) may be assumed without reaching the static value of 100 pounds per square foot for which such a stand would probably be designed. Provision against horizontal effect, however, is not commonly made, and the importance of some such provision is illustrated by the experiment. To be on the safe side, a backward horizontal impulse of 70 or 80 pounds for each sitting might wisely be guarded against.

The "jouncing" movement, while it has a high kinetic intensity and is possible in a much denser throng than in Experiments I and II., is nevertheless of much shorter duration; the effect is that of a rather sharp, quick blow. On this account, practically perfect synchronism of movement is necessary to get the maximum effect, and this, of course, is quite impossible in any ordinary crowd.

The horizontal effect resulting from a man walking is probably not of general importance, except in the case of a large number of men marching in cadence, as a body of soldiers. The evil effect of this on bridges has been recognized for generations, and the tactical requirement of "breaking step" during the passage of a bridge by infantry is well known. Mention might be made of the obvious slight variations in vertical load effect during the phases of a stride (in Fig. 8, it is seen that 4 and 9 are high positions and 1, 6 and 12 are low positions of the man's center of gravity), but these movements are small compared with those of Fig. 1 and Fig. 3.

The experiment of running across a bridge is perhaps rather more difficult of application to a

[1] This series of figures was traced from plate 2 of volume I. of "Animal Locomotion," by Eadweard Muybridge (Philadelphia, 1887). This remarkable work, published in eleven great volumes, shows literally thousands of photographs of human beings and animals in great variety of motion. A smaller edition, containing a few of the series, much reduced in size, has been published under the title "The Human Figure in Motion." (London, Chapman and Hall, 1901.)

[2] Force (in pounds) = mass × acceleration, the mass being measured in "engineers' units" (1 unit = 32.2 pounds) and the acceleration in feet per second per second.

crowd. If a line of men, each weighing 150 pounds, were distributed at intervals of, say, 18 inches along the railing of a bridge, and at a given signal, turned and ran to the other side, bringing up sharply against the opposite rail, the lateral force exerted might even exceed the usual allowance made for wind. Something of the kind, undoubtedly, may occur under certain conditions, but to what extent it should be guarded against is again a matter of individual judgment based on the exigencies of a particular problem. A further application of this experiment, however, might be mentioned. A wharf or pier, used for excursion boats, may collect a large number of people who enter from the land singly or in groups and come to rest on the structure. In coming to rest a horizontal force is exerted, that is, kinetic energy is destroyed, tending to push the wharf out into the water; and this force is applied as a succession of blows, all in the same direction.

The same is true of any elevated platform, or structure, built for the accommodation of men and women, the entrance to which is restricted to only one line of movement. Such a structure is bound to receive shocks or impulsive horizontal forces in the manner indicated. That these effects are generally so small as to be of no importance is quite true; but that they may also on occasion reach considerable proportions, and especially that the cumulative effect may be serious, seems to be equally beyond question. It may be that a bridge, or pier, or platform may be fully capable of carrying all ordinary loads, even to a densely packed crowd of people, but some day it gives way under a much less (static) load. Is it not possible that the failure may be due to a peculiar combination of movements, on the part of the individuals of the crowd, timed and synchronized so that a force effect is produced on the structure far greater than that of the mere dead load?

In conclusion, it may be said that the evidence submitted hardly warrants any dogmatic statement as to what loads should be considered in providing for the possible effects of motion in crowds of people. The results of the experiments are not scientifically exact, nor are the applications definite or precise; but that some provision should be made against effects which are shown to be probable in an excited gathering, there can be no doubt. It is a matter for the individual engineer to determine, in solving his particular problem. The facts, albeit with some uncertainties and many qualifications, are presented as they appeared in the actual experiments described. They should be interpreted and used in the light of sound common sense, fair and impartial engineering judgment, and, above all, a due sense of the responsibility that rests on the architect or engineer for the safety of those who must use his construction.

A Synopsis of Radiations and Their Characteristics

A Convenient Table Showing at a Glance the Principal Properties of Wave and Corpuscular Radiations

It is a somewhat remarkable fact that in the evolution of our modern views of the constitution of matter, the study of radiations has furnished some of the most significant clews. And this is true not only with regard to the undulatory radiations carried through space (or through the ether as the case may be), the radiations of which light is the characteristic example; but it is true, perhaps, even in greater measure, with regard to the corpuscular radiations, which are at the present day proved beyond all question to consist of particles of matter or electricity traveling at speeds varying from one millimeter per second (slow canal rays) to the neighborhood of the velocity of light, 3×10^8 meters or 186 thousand miles per second.

The mere measurement of the velocity of light was in itself a somewhat dramatic accomplishment, although we have become so familiar with the work of Fizeau, Foucault and their more modern successors that perhaps we are somewhat deadened to the realization of their remarkable achievements. But recent developments, especially in the study of corpuscular radiations, have put these older researches entirely in the shade. And there is a close relation between the two types of radiation. For we know from the labors of Maxwell and Hertz that light is an electro-magnetic disturbance, while one of the principal interests attached to the study of corpuscular radiations is that they also are closely related to certain electrical phenomena, inasmuch as in the majority of cases a corpuscle carries an electric charge, and indeed, in certain cases it appears to consist of nothing but an electric charge. Herein lies the cause for the fact that the velocity of a corpuscular ray cannot exceed that of light, though it may approach closely to it, and does so in certain instances; and here also is furnished the means of measuring the elementary charge of electricity, the "atom" of electricity, as shown by the labors of C. T. R. Wilson, R. A. Millikan, and others.

Our readers have been made familiar by a series of articles, many of them products of the genius of Sir J. J. Thomson, others from the pen of Prof. Joly, Prof. Bragg and others, with some of the principal properties of corpuscular radiations, the brilliant methods of studying their properties, and their wonderful applications to chemical analysis, to the solution of the problem of the age of the earth, of the origin of the elements and so forth. It is not intended here to restate any of the facts previously thus recorded, but merely to give, in the accompanying table, a brief synopsis of the principal properties of each type of radiation. It is hoped that this table will be found valuable by all those who have been following the subject with the high interest which it deserves.

TABLE SHOWING CHARACTERISTICS OF DIFFERENT TYPES OF RADIATIONS KNOWN AT THE PRESENT DAY.*

* Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *Die Umschau*.

[NOTE: 10^6 = one million; 10^7 = ten millions; 10^8 = one hundred millions.]

I.—Wave Radiations.

(Propagated like water or sound waves without transfer of matter along path of propagation.)

General Characteristics: All radiations of this class are propagated with the same constant velocity through empty space, namely, at a speed of 186,300 miles per second. They also display the phenomena of polarization and interference.

Name.	Wave Length.	Source or Mode of Origin.	Special Properties and Practical Applications.
Electro-magnetic or Hertzian waves	3 millimeters to several thousand meters. (1-10 inch to several thousand yards)	Electrical discharges	Wireless telegraphy
Infra-red or Heat Rays	0.06 to 0.00076 millimeter	Hot bodies	Recognized by their heating effects
Visible Rays	0.00076 to 0.0004 millimeter	Incandescent bodies, etc.	Ordinary light
Ultra-violet Rays	0.0004 to 0.0001 millimeter	White hot bodies; mercury vapor lamp	Actinic (chemically active) portion of light (e. g., affect photographic plate, though not visible to the eye). Bactericidal action. Ionize the air on passage therethrough
X-Rays, γ-Rays	About 0.0000005 millimeter	Produced by impact of cathode rays on various substances. Also emitted by radio-active materials	Penetrate opaque bodies. Ionize the air. Important diagnostic and therapeutic applications in medicine

II.—Corpuscular Radiations.

(Consisting of streams of small particles projected at high velocities.)

General Characteristics: Can be deflected by an electric or magnetic field. Ionize the air traversed.

A. Rays of negatively charged particles (electrons, with a mass equal to about 1/1000 that of a hydrogen atom).

Name	Velocity (Characteristic of the Particular Type of Ray)	Source or Mode of Origin	Special Properties and Practical Applications
β-Rays	10^8 to 3×10^8 meters per second	Radio-active bodies	Traverse comparatively thin layers of opaque bodies. Applied in medicine to treatment of ulcers
Ordinary (Fast) Cathode Rays	22 to 50 $\times 10^6$ meters per second	Electric discharges in vacuum bulbs	Traverse only very thin layers of material, such as fine metal foil
Slow Cathode Rays	1,000 to 0 meters per second	Incandescent bodies, chemical reactions	Absorbed by any material, even air, in thin layers. Can therefore be observed only *in vacuo*

B. Rays of positively charged particles (atoms or molecules carrying one or more electric charges).

α-Rays	1.6×10^7 millimeters per second (about 1-20 the velocity of light *in vacuo*)	Radio-active bodies	Traverse very thin layers, e. g., metal foil
Canal Rays	1 to 10^6 millimeters per second	Electrical discharges in vacuum bulbs	Absorbed by very thin layers of matter

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

Curiosities in Numbers

In our issue of July 19th, 1913 (page 42), a correspondent drew attention to the following relations:

$$(a)\quad 1^3+2^3+3^3+\ \ldots\ +n^3=(1+2+3+\ \ldots\ +n)^2$$

$$(b)\quad 1^2+2^2+3^2+\ \ldots\ +n^2=(1+1)+2(1+2)+2(1+2+3)+\text{ etc. }+(1+2+3+\ \ldots\ +n).$$

We invited our readers to send in proofs of these relations. Many responses were received, of which a selection is published below:

To the Editor of the SCIENTIFIC AMERICAN SUPPLEMENT:

SOLUTION I.

We may establish the identity

$$1^2+2^2+3^2+4^2+\ldots\ldots+n^2\equiv 2\times 1+2(1+2)+2(1+2+3)+\ldots\ldots+2\{1+2+3+\ldots\ldots+(n-2)+(n-1)\}+1+2+3+4+\ldots\ldots+n$$

as follows:

We have

$$n^2\equiv(n^2-n)+n$$
$$\equiv n(n-1)+n$$

But

$$n(n-1)=2\{1+2+3+4+\ldots\ldots+(n-1)\}$$ (arithmetical progression).

Therefore:

$$n^2=2\{1+2+3+4+\ldots\ldots+(n-2)+(n-1)\}+n$$
$$(n-1)^2=2\{1+2+3+4+\ldots\ldots+(n-2)\}+(n-1)$$
$$(n-2)^2=2\{1+2+3+4+\ldots\ldots+(n-3)\}+(n-2)$$
$$\ldots\ldots\ldots\ldots$$
$$4^2=2(1+2+3)\qquad +4$$
$$3^2=2(1+2)\qquad +3$$
$$2^2=2(1)\qquad +2$$
$$1^2=2\times 0\qquad +1$$

Now, adding both sides, we obtain:

$$1^2+2^2+3^2+4^2+\ldots\ldots+(n-1)^2+n^2\equiv 2\times 0+2\times 1+2(1+2)+2(1+2+3)+2(1+2+3+4)+\ldots\ldots+2\{1+2+3+4+\ldots\ldots+(n-1)\}+1+2+3+4+\ldots\ldots+n.$$ Q. E. D.

In passing I may add that for the sake of conformity the form

$$1^2+2^2+3^2+\ldots\ldots+n^2=2\times 1+2(1+2)+2(1+2+3)+2(1+2+3+4)+\ldots\ldots+2\{(1+2+3+4+\ldots\ldots(n-1)\}+1+2+3+4+\ldots\ldots+n$$

is a trifle preferable over that given by your correspondent, namely:

$1^3+2^3+3^3+\ldots.+n^3=(1+1)+2(1+2)+2(1+2+3)+\ldots.$
$+1+2+3+4+\ldots.+n.$

Detroit, Mich. T. I. Wodo.

SOLUTION II.

(a)
To prove
$$1^3+2^3+3^3+\ldots.n^3=(1+2+3+\ldots.n)^2$$
Assume first the truth to n terms.

Then the result of adding the $(n+1)$th term on either side will be to add to the equation as follows:

On the left: $(n+1)^3$

On the right: $(n+1)^2+2(n+1)\,(1+2+3+\ldots.n)$

But $(1+2+3+\ldots.n)$ is the sum of an arithmetical progression and equals $\frac{n}{2}\,(n+1)$.

Hence, the added terms on the right reduce to
$$(n+1)^2+2(n+1)\frac{n}{2}\,(n+1)=(n+1)^2(n+1)=(n+1)^3$$
Hence, the added terms on each side of the equation balance.

Hence, if the relation is true for n terms it is true for $(n+1)$ terms.

But observation shows that it is true for $n=1$. Hence, it is true for $n=2$, 3, etc., to n=any real number no matter how large, and hence it is true in general.

(b)
To prove
$$1^3+2^3+3^3+\ldots.n^3=(1+1)\;+2(1+2)\;+2(1+2+3)\;+(1+2+3+\ldots.n)$$
Here likewise assume first the truth of the relation to n terms.

Then the result of adding the term $(n+1)$ on either side will be to add to the equation as follows:

On the left: $(n+1)^3$

On the right: $(1+2+3+\ldots.n)$
$+(1+2+3+\ldots.\;(n+1))$.

But these are two arithmetical progressions and summing we have:
$$S=\frac{n}{2}(n+1)+\left(\frac{n+1}{2}\right)(n+2)$$
$$=(n+1)(n+1)=(n+1)^2.$$
Hence, the added terms on each side of the equation balance.

Hence, if the relation is true for n terms it is true for $(n+1)$ terms.

But observation shows that it is true for $n=1$ or 2 or 3.

Hence, it is true for n=any real number no matter how large, and hence it is true in general.

It may be noted that the right hand member in the above general equation is more consistently written as follows:
$$(1+2+3+\ldots.n)+2\,(1+2+3+\ldots.n-1)$$
$$+2(1+2+3+\ldots.n-2)$$
$$+\ldots\ldots2\,(1+2+3)+2\,(1+2)+2\,(1).$$
W. F. Durand.

SOLUTION III.

Problem (a)
$$1^3+2^3+3^3\ldots.n^3=(1+2+3+\ldots.n)^2. \quad (1).$$
Write out the left hand member in full:
$$1+8+27+64+125 \quad (2)$$
Using the differential method of solution:

$d_1=$	7	19	37	61
$d_2=$	12	18	24	
$d_3=$	6	6		
	0			

(See Well's College Algebra page 425).

The formula for the sum of the series (2) is:
$$S=n+\frac{n(n-1)}{2}\,d_1+\frac{n(n-1)(n-2)}{3!}\,d_2+\frac{n(n-1)\ldots.(n-3)}{4!}\,d_3$$
where $d_1=7$ $d_2=12$ $d_3=6$

Then
$$S=n+\frac{7n(n-1)}{2}+2(n)(n-1)(n-2)+\frac{n(n-1)(n-2)(n-3)}{4} \quad (3)$$
Adding these terms
$$S=\frac{n^4+2n^3+n^2}{4} \quad (A)$$
On the right hand side of (1) is an ordinary arithmetical progression
$$\therefore \text{its sum}=\left\{\frac{n(n+1)}{2}\right\}^2=\frac{n^2(n^2+2n+1)}{4}=\frac{n^4+2n^3+n^2}{4} \quad (B)$$
A comparison of (A) and (B) furnishes the required proof.

Problem (b)
$$1^3+2^3+3^3+\ldots n^3=2\{1\}+2\{1+2\}+2\{1+2+3\}\ldots+\{1+2+3\ldots.n\}.$$
Writing out the left hand side in full and adding by the differential method:

	1	4	9	16
$d_1=3$		5	7	
$d_2=$	2	2		
	0			

$$S=n+\frac{n(n-1)}{2}.\,3+\frac{n(n-1)(n-2)}{3}$$
$$=\frac{n}{6}\{2n^2+3n+1\}=\frac{n(n+1)(2n+1)}{6} \quad (A)$$
On the right hand side the terms may be arranged
$$2\{1+3+6+10+15\ldots.\}+\{1+2+3\ldots.n\}.$$
The first bracket here has plainly $(n-1)$ terms.

Add this also by the differential method:

1	3	6	10	15
$d_1=2$	3	4	5	
$d_2=1$	1	1		
0	0			

$$S=(n-1)+(n-1)\,(n-2)+\frac{(n-1)(n-2)(n-3)}{6}$$
$$=(n-1)\left\{(n-1)+\frac{(n-2)(n-3)}{6}\right\}$$
$$=(n-1)\left\{\frac{(6n-6+n^2-5n+6)}{6}\right\}$$
$$=(n-1)\left\{\frac{n^2+n}{6}\right\}\quad\text{Whence } 2S=\frac{n(n-1)(n+1)}{3}$$
Adding the two terms of (5)
$$\frac{n(n-1)(n+1)}{3}+\frac{n(n+1)}{2}=\frac{n(n+1)(2n+1)}{6} \quad (B)$$
Again, comparison of (A) and (B) furnishes the required proof.

R. C. Colwell.

SOLUTION IV.

(a) Let general term of series equal U_n.

Then $U_n\equiv n^3=n(n+1)(n+2)-3n^2-2n$
$=n(n+1)(n+2)-3n(n+1)+n.$

By a well known algebraic formula, we find that the sums of the series of which $n(n+1)(n+2)$, $3n(n+1)$, and n are the general terms, are equivalent to
$$\frac{1}{4}\,n(n+1)(n+2)(n+3),\ \frac{3}{3}\,n(n+1)(n+2),\ \text{and}$$
$$\frac{1}{2}\,n(n+1).$$
Therefore,
$$1^3+2^3+3^3+\ldots.+n^3=\frac{1}{4}n(n+1)(n+2)n(+3)$$
$$-\frac{3}{3}n(n+1)(n+2)+\frac{1}{2}\,n(n+1)$$
$$=\frac{1}{4}n(n+1)\{(n+2)(n+3)-4(n+2)+2\}$$
$$=\frac{1}{4}\,n^2(n+1)^2$$
Since

$1+2+3+\ldots.+n=\frac{1}{2}\,n(n+1)$, the above result shows that
$$1^3+2^3+3^3+\ldots.+n^3=(1+2+3+\ldots.+n)^2\ \text{Q.E.D.}$$
(b) It can be proved by ordinary algebraic formula that
$$1^2+2^2+3^2+\ldots.+n^2=\frac{n(n+1)(2n+1)}{6}$$
But the series $(1+1)+2(1+2)+2(1+2+3)$
$+\ldots.+2(1+2+3+\ldots.+n)$

is equivalent to
$$\{1.2+2.3+3.4+\ldots+n(n+1)\}-1-2-3-\ldots-n.$$
But $1.2+2.3+\ldots.+n(n+1)=\frac{n(n+1)(n+2)}{3}$, and

$1+2+3+\ldots.+n=\frac{n(n+1)}{2}$.

Hence, $\frac{n(n+1)(n+2)}{3}-\frac{n(n+1)}{2}=\frac{n(n+1)(2n+1)}{6}$,

which is equal to $1^2+2^2+3^2+\ldots.+n^2$.

Brudenell, Ont; Canada. Peter Drohan.

*[The following method is of particular interest. It is based on the consideration that the series given is a function of n and may, therefore, be expressible in the form of a power series. This power series must stop at the fourth power, because equation (3) below must evidently stop at the third power.—*Ed.]

SOLUTION V.

(a)

Let $1^3+2^3+\ldots.+(n+1)^3=A+B\,(n+1)+C(n+1)^2+D\,(n+1)^3+E\,(n+1)^4 \quad (1)$

and $1^3+2^3+\ldots.+n^3=A+Bn+Cn^2+Dn^3+En^4 \quad (2)$

Subtracting we have:
$$(n+1)^3=B+C+D+E+n(2C+3D+4E)+n^2(3D+6E)+4En^3 \quad (3)$$
which gives
$$E=\frac{1}{4}\quad D=\frac{2}{4}\quad C=\frac{1}{4}\quad B=0\quad A=0 \quad (4)$$
Hence,
$$1^3+2^3+\ldots.+n^3=\frac{n^4+2n^3+n^2}{4} \quad (5)$$
On the other hand
$$(1+2+\ldots.n)^2=\left\{\frac{n}{2}(n+1)\right\}^2=\frac{n^4+2n^3+n^2}{4} \quad (6)$$
So that
$$1^3+2^3+\ldots.+n^3=(1+2+\ldots.+n)^2 \quad (7)$$
This proves that if the given equation is true for n it is also true for $(n+1)$. It remains to show that it is true for some particular value of n, say $n=3$.
$$1^3+2^3+3^3=36=(1+2+3)^2.$$
Hence, the equation given is true for all values of n.

The same method of proof may be applied to problem (b).

Leavenworth, Kansas. X. Y. Z.

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